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Peter Born and M.W. Hitch

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Foreword

The Bay Lake area, located immediately west of the Cobalt mining camp, is underlain primarily by metasedimentary rocks of the Huronian Supergroup and Nipissing diabase sills of Middle Archean age, with minor inliers of Archean metavolcanic rocks. Although these rocks are similar to those of the Cobalt camp, the area had been mapped at only a reconnaissance scale prior to the detailed mapping which is reported here. This mapping was undertaken to provide a comprehensive geological data base for mineral exploration and land use planning.

The rocks of the Bay Lake area contain numerous polymetallic mineral occurrences of copper, cobalt, silver and minor gold. Although there are no currently producing mines in the area, its potential to host economic deposits is considered good.

The work reported here was funded under the five-year Canada-Ontario Mineral Development Agreement (COMDA), a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the government of Canada and Ontario.

V.G. Milne
Director
Ontario Geological Survey

Abstract

This report describes the geology, stratigraphy, structure and mineral occurrences of the Bay Lake area. The 240 km² map area covers the western part of Coleman Township and the southern two-thirds of Gillies Limit Township. It is located in the District of Timiskaming about 8 km southwest of Cobalt. Precambrian rocks of Archean and Proterozoic age are covered by a thin veneer of Cenozoic glacial deposits.

Archean rocks of the Superior Province underlie the southwestern and northeastern parts of the map area, and consist mainly of felsic plutonic, mafic metavolcanic and lesser felsic metavolcanic rocks.

Mafic metavolcanic rocks consist of pillowed komatiitic basalt, calc-alkalic plagioclase-phyric andesites, tholeiitic amphibolites and minor synvolcanic komatiitic intrusive rocks. The intermediate to felsic volcanics consist mainly of calc-alkalic pyroclastics and minor flows. Felsic plutonic rocks in the southwest consist of a heterogeneous assemblage of mafic diorite, quartz diorite, tonalite and granodiorite. In contrast, the plutonic rocks in the northeast region consist of a single homogeneous granite intrusive body.

Proterozoic rocks underlie all other parts of the map area and consist of sediments of the Huronian Supergroup, Nipissing intrusive rocks and minor mafic and lamprophyre dikes.

The local Huronian stratigraphy consists of the Gowganda and Lorrain formations of the Cobalt Group. Sedimentary rocks of the Gowganda Formation are subdivided into a lower Coleman Member and an upper Firstbrook Member. Rocks of the Coleman Member unconformably overlie the Archean basement, and consist of a basal conglomerate, matrix- and clast-supported conglomerates, pebbly wackes, arkoses and mudstones.

Sediments of the Firstbrook Member conformably overlie the Coleman Member and consist of laminated mudstones, siltstones and arenites.

Sediments of the Lorrain Formation consist mainly of arkoses and conformably overlie the Gowganda Formation throughout the Bay Lake area.

Deposition of the Coleman Member probably occurred in a subaqueous environment near the grounding line of a continental glacier. The Firstbrook Member and the Lorrain Formation were deposited as a southward-prograding, coarsening-upwards marine clastic wedge fed by a braided fluvial system, possibly South Saskatchewan River type. Upward facies transitions are from prodelta through delta slope and foreslope, to tidal flat and channel, overlain by braided fluvial topset beds. Subsequent deposition of the Lorrain Formation occurred as several episodic marine transgressions. It inundated the exposed fluvial braid plain and reworked most of the arkosic topset beds and redeposited them in a shallow inner shelf marine environment.

The Huronian sedimentary sequence was intruded by several Nipissing diabase sills consisting of quartz gabbro, lesser varied-textured quartz gabbro, hypersthene gabbro and minor granophyre. Contact metamorphism resulted in local spotted chlorite alteration mainly within adjacent arkoses of the Lorrain Formation.

The youngest Precambrian rocks in the area are northwest-trending olivine diabase dikes of the Sudbury Swarm (1240 Ma). Lamprophyre dikes are probably of a similar age and contain rounded accidental clasts of Archean rock types. The vertical dikes are uncommon and generally trend in a northerly direction. They could be related to tectonic events associated with the Timiskaming Rift System.

Deformation and lower greenschist metamorphism occurred after the emplacement of the Nipissing diabase sill (2219 Ma) during the Penokean Orogeny some 1900 Ma. Only minor folding occurred.

Locally extensive, postdepositional breccias are associated with compressional kink bands and occur within the rocks of the Gowganda and Lorrain formations. The proximity of such zones to Nipissing diabase suggests that they may represent water escape processes related to the intrusion of the sills. In other cases the breccias straddle a northwest-trending zone parallel to the Latchford Fault and could be related to tectonic movement along that northwest-striking fracture zone.

Later Lake Temagami-type breccias may also represent gas escape features and/or may be related to lamprophyre dikes associated with the Timiskaming Rift System.

Extensive prospecting for silver and cobalt since 1906 has resulted in the discovery of numerous occurrences of copper, cobalt and silver in the Bay Lake area. Polymetallic-bearing veins of these metals are hosted within either the upper or lower contacts of Nipissing diabase sills, or in narrow diabase dikes or in adjacent Archean metavolcanics or sediments of the Gowganda Formation. The geological environment is favourable for new discoveries of copper, cobalt and silver and possibly gold mineralization in close proximity to Nipissing diabase rocks.

Born, Peter and Hitch, M.W. 1990. Precambrian geology, Bay Lake area; Ontario Geological Survey, Report 276, 81p.

Résumé

Ce rapport décrit la géologie, la stratigraphie, la structure et les minéralisations dans la région de Bay Lake. La zone cartographiée couvre une surface de 240 km² et comprend la partie occidentale du canton de Coleman et les deux-tiers sud du canton de Gillies Limit. Elle est située dans le district de Timiskaming à environ 8 km au sud-ouest de Cobalt. Les roches précambriennes d'âge Archéen et Protérozoïque sont recouvertes d'une mince couche de dépôts glaciaires du Cénozoïque.

Les roches archéennes de la province Supérieure se situent dans les parties sud-ouest et nord-est de la zone cartographiée. Elles comprennent principalement des roches plutoniques felsiques, des roches métavolcaniques mafiques et plus rarement des roches métavolcaniques felsiques.

Les roches métavolcaniques mafiques sont composées de basaltes komatiitiques à coussinets, d'andésites calco-alcalines à phénocristaux de plagioclase, d'amphibolites tholéitiques et de quelques roches intrusives komatiitiques syn-volcaniques. Les roches volcaniques de composition intermédiaire à felsique sont composées principalement de dépôts pyroclastiques et de quelques coulées. Les roches plutoniques felsiques dans le sud-ouest de la zone cartographiée constituent un assemblage hétérogène de diorite mafique, diorite quartzique, tonalite et granodiorite. Par contre, les roches plutoniques dans la région nord-est forment une seule masse intrusive homogène de granite.

Les roches protérozoïques se trouvent dans toutes les autres parties de la zone cartographiée et comprennent des sédiments appartenant au supergroupe de l'Huronien, des roches intrusives de Nipissing et quelques dykes mafiques et lamprophyriques.

La stratigraphie dans cette partie du supergroupe de l'Huronien comprend les formations de Gowganda et de Lorrain qui, toutes les deux, font partie du groupe de Cobalt. Les roches sédimentaires de la formation de Gowganda sont subdivisées en deux membres, le membre de Coleman et le membre sus-jacent de Firstbrook. Les roches du membre de Coleman reposent de façon discordante sur le soubassement archéen et sont constituées d'un conglomérat basal, de conglomérats à fort ou faible pourcentage de cailloux, des grauwackes caillouteux, d'arkoses et de mudstones.

Les roches sédimentaires du membre de Firstbrook reposent de façon concordante sur le membre de Coleman. Celles-ci comprennent des mudstones feuilletés, des microgrès et des arénites.

Les roches sédimentaires de la formation de Lorrain sont formées surtout d'arkoses qui sont sus-jacentes à la formation de Gowganda dans toute la zone de Bay Lake.

L'accumulation sédimentaire du membre de Coleman s'est probablement produite dans un milieu sub-aquatique en marge d'un glacier continental. Les sédiments des membres de Firstbrook et de la formation de Lorrain se sont accumulés en milieu marin progressant vers le sud et dont le granoclassement augmente vers le haut. Cette accumulation sédimentaire a été alimentée par des rivières anastomosées, peut être du type de la rivière South Saskatchewan. Les transitions dans les faciès supérieurs vont des dépôts de pro-delta aux dépôts d'estran et de chenaux en passant par des dépôts de pentes deltaïques et d'avant-pentes, qui sont recouverts de lits deltaïques sommitaux. Des dépôts ultérieurs appartenant à la formation de Lorrain se sont produits à la suite de plusieurs transgressions marines épisodiques. Celles-ci ont eu pour effet d'inonder la plaine fluviale anastomosée et de remanier la plupart des lits deltaïques sommitaux arkosiques pour les redéposer dans des hauts-fonds intérieurs de faible profondeur.

La séquence sédimentaire de l'Huronien a été intrudée par plusieurs filons-couche de diabase de Nipissing. Ce diabase est constitué de gabbro quartzique avec des quantités moindres de gabbro quartzique à texture variée, de gabbro à hypersthène et de quelques granophyres. Le métamorphisme de contact a eu pour effet de produire une altération qui se manifeste par une chloritisation locale, surtout au sein des arkoses adjacentes de la formation de Lorrain.

Les roches précambriennes les plus jeunes dans le secteur sont représentées par des dykes de diabase à olivine de direction nord-ouest qui appartiennent à l'essaim de

Sudbury (1240 Ma). Des dykes de lamprophyre sont probablement d'âge similaire et ont la particularité de contenir occasionnellement des fragments de roches archéennes. Ces dykes verticaux sont peu communs et sont orientés vers le nord-est. Ils pourraient également être liés à des événements tectoniques associés au système de décrochement de Timiskaming.

Une déformation et un métamorphisme du faciès inférieur des schistes verts se sont produits au cours de l'orogénèse Pénokéenne (environ 1900 Ma) après l'emplacement du filon-couche de diabase de Nipissing (2219 Ma). Seuls des plissements mineurs se sont produits.

Importantes par endroit, des brèches postérieures à la sédimentation, sont associées à des bandes de flexure dues à la compression et se trouvent dans les roches des formations de Gowganda et Lorrain. La proximité de telles zones avec le diabase de Nipissing suggère qu'elles sont liées au processus d'évacuation des eaux engendré par l'intrusion des filons-couche. Par ailleurs, on trouve des brèches dans une zone orientée nord-ouest, parallèle à la faille de Latchford. Ces brèches pourraient être liées aux mouvements tectoniques le long de cette zone de fracture de direction nord-ouest. Ultérieurement, des brèches du type de celles que l'on trouve près du lac de Temagami peuvent également représenter des structures dues à l'évacuation des gas et/ou sont liées aux dykes de lamprophyre associés au système de décrochement de Timiskaming.

Depuis 1906, dans la région de Bay Lake, une intense prospection de l'argent et du cobalt s'est traduite par la découverte de nombreux indices minéralisés de cuivre, de cobalt et d'argent. Des veines polymétalliques contenant ces métaux se trouvent soit aux contacts inférieurs des filons-couche de diabase de Nipissing, soit dans des dykes de diabase peu épais, ou bien encore, dans les roches métavolcaniques archéennes ou dans les roches sédimentaires de la formation de Gowganda qui sont adjacentes à ces intrusions. L'environnement géologique est favorable à de nouvelles découvertes de cuivre, de cobalt, ou d'argent et peut-être de minéralisations aurifères à proximité des diabases de Nipissing.

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Precambrian Geology Bay Lake Area

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Introduction

LOCATION AND ACCESS

The map area (240 km²) consists of the western part of Coleman Township and most of the southern two-thirds of Gillies Limit Township. It is located in the District of Timiskaming about 8 km southwest of Cobalt, 20 km north of Temagami and 120 km north of North Bay, and bounded by latitudes 47°13'00"N and 47°23'00"N and longitudes 79°55'00"W and 79°38'00"W (Figure 1).

Excellent access is provided by Highway 11 and a series of connected secondary lumber roads and by Bay Lake and the Montreal River. Entry by floatplane onto Island, Second Justin, Coleman, Hound Chute and Roosevelt lakes provides access to the remainder of the area.

PREVIOUS GEOLOGICAL WORK

Local silver and cobalt exploration began following the discovery of silver around Cobalt in 1904. The Bay Lake map area is located about 8 km to the southwest of the town of Cobalt.

The earliest geological mapping in the area was done on a reconnaissance scale by Barlow (1899), DeLury (1913), Miller (1913) and Todd (1926). Subsequent and more detailed mapping in adjacent areas to the north of the Bay Lake area was done by Thomson (1963a, 1963b, 1963c) and Johns (1985). The present survey overlaps slightly with some of the detailed mapping of Thomson (1960, 1961, 1963a, 1963b, 1963c) in the area

along Highway 11, north of Latchford. Mapping to the southeast in South Lorrain Township was completed by McIlwaine (1970), and adjacent Lorrain Township was mapped by Lovell and de Grijjs (1976). Areas to the west of the Bay Lake area include Banting and Best townships which were mapped by Smyk and Owsiacki (1986) whereas adjacent Brigstocke and Kittson townships were mapped by Born and Burbidge (1987).

The regional Quaternary geology of the area is portrayed on Ontario Geological Survey Map 5024 (Haileybury) by Roed (1979). The regional geology map is Map 2361, Sudbury-Cobalt sheet (Card and Lumbers 1977) and the regional aeromagnetic maps are GSC Aeromagnetic Series maps 1491G (GSC 1965a) and 1492G (GSC 1965b).

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The authors each mapped approximately 40 percent of the project area during the 1988 field season. The remainder was mapped by Angelo Avlonitis during the second half of the summer. In addition, the field crew included geological assistants Susan Gray and Mairi Best.

The authors acknowledge assistance in the preparation of all the figures and other duties that contributed greatly to the completion of this manuscript. Thus, we gratefully acknowledge Ann Lesage, Scott Jeffery, Jill Stewart and Gail Soberman, who were all geological assistants with the Ontario Geological Survey Precambrian Geology Section during the winter of 1988-89.

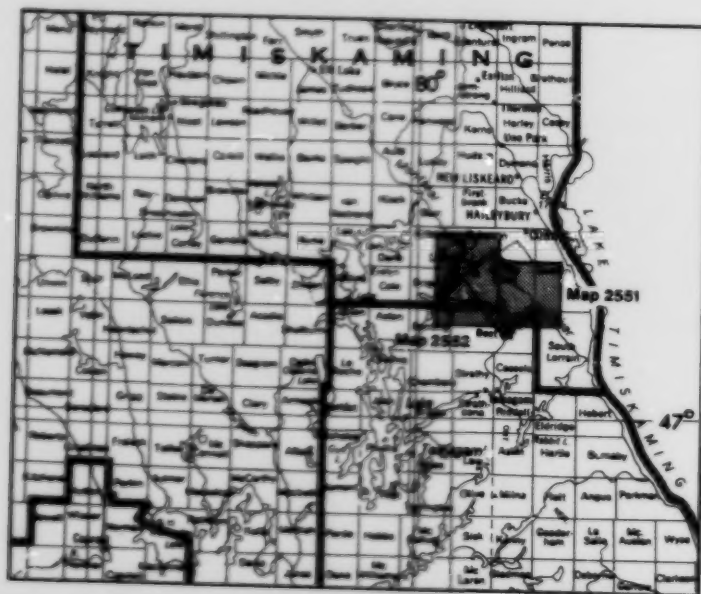


Figure 1. Key map showing location of the Bay Lake area, scale 1:158 400.

The authors wish to thank the staff of the Ministry of Natural Resources in Temagami for continued assistance during the summer. The staff of the Cobalt Resident Geologist's office are also thanked for their valuable assistance during the field season.

TOPOGRAPHY AND DRAINAGE

Average relief in the map area is approximately 50 to 80 m with some high hills and cliffs along some of the long and narrow northeast-trending lakes. The lowest elevation is 266 m at the Montreal River in the southeast corner of the area. The maximum elevation is 437 m at two localities, one is just east of Island Lake and the other is east of Rib Lake. Both are near the southern limit of the map area.

In areas underlain by Archean rock types and Early Proterozoic Nipissing diabase, bedrock exposure is approximately 20%. This covers mainly the southeast and northeast corners of the map area. Elsewhere, the exposures are poor except along lakeshores and creeks. In these areas, which are mainly underlain by Proterozoic sedimentary rocks, the exposure is approximately 5 to 10%.

Some differences in bedrock types and structure may control local variations in topographic relief. Proterozoic sediments are commonly exposed along lakeshores in long linear, northwest-trending cliffs and ridges parallel to their strike and to the main joint and fault direction. An example of this good exposure is along the scarps associated with the northwest-trending Latchford Fault that cuts through Rib, Johnson and Bay lakes. Little is exposed in valleys and plateaus between the ridges or away from the lakeshore. Nipissing diabase also occurs as prominent steep scarps and forms an east-trending ridge in the southern part of the map area between Island and Johnson lakes. Archean rock types are exposed, however, in a rolling terrain with more continuous bedrock in a series of low and flat outcrops.

Water covers approximately 10% of the area, with Bay Lake being the largest body of water. Other lakes are Rib, Johnson, Island, Roosevelt, Schumann, Hearst, Friday, Wilson, Prud'homme, Bryan, Coleman and Justin lakes. The most prominent body of water, however, is the Montreal River which transects the entire map area. All of the lakes drain into the Montreal River which eventually flows into the Lake Timiskaming-Ottawa River System to the east of the map area.

General Geology

Underlying the map area are Archean supracrustal and plutonic rocks, Early Proterozoic supracrustal and intrusive rocks and Middle Proterozoic diabase and lamprophyre dikes (Figures 1, 2, 3, 4 and 5). Cenozoic sediments comprise the youngest lithologic units in the area and are represented by Pleistocene and Recent gravels, sand and organic debris.

A generalized summary of the rock types occurring within the Bay Lake area is given in Table 1.

ARCHEAN

Archean rocks underlie the southwest and northeast parts of the map area and consist mainly of felsic plutonic and migmatitic rocks with lesser mafic and minor associated metavolcanics. All other areas are underlain by Proterozoic rocks.

The felsic plutonic rocks in the southwest consist of a heterogeneous assemblage of biotite- and hornblende-bearing tonalite, quartz diorite, mafic diorite and diorite. In contrast, only granites occur in the northeast corner of the area.

Archean rocks mainly underlie the southwest and northeast corners of the map area and consist of metavolcanic and metaplutonic rocks.

Metavolcanic Rocks

MAFIC TO INTERMEDIATE METAVOLCANIC ROCKS

The petrography of the main rock types are summarized in Table 2. A microscopic description is given below.

Some metavolcanics occur as fine- to medium-grained amphibolites (map unit 1a). These rocks are located mainly in the southwest corner of the map area. They can also occur as fine-grained remnants hosted within the granodiorite and cut by local minor (10%) veins and veins of granodiorite. Textures within the amphibolitic rocks suggest partial digestion by the intrusive granitoid rocks and local partial melting as indicated by paleosome bands, feldspar porphyroblasts and other migmatitic features. These features are better developed to the west of the map area and are more fully described in Born and Burbidge (in press).

In thin section, granoblastic textures indicate recrystallization with lepidoblastic hornblende and actinolite followed by some retrograde alteration of plagioclase to epidote and muscovite. In one sample the presence of abundant serpentine and hypersthene in a typical retrograde mineral assemblage suggests magnesium-rich volcanic rocks of probable komatiitic or komatiitic basalt affinity. The magnesium-rich nature of the

chlorites also suggests a relatively magnesium-rich source rock.

Generally the most common mafic metavolcanic rock type is fine-grained, massive metabasalt (map unit 1b). This rock type occurs at several locations. In the Borden Lake area the metabasalts are weakly foliated and intruded by granites. In the nearby Chopin Lake area, they exhibit characteristic bulbous weathering and fractures, and possess flow features and fine-grained chilled margins. Minor pyrite is a common accessory mineral. Commonly, these massive flows are locally intercalated with plagioclase-phyric basalts. Elsewhere in the southern part of the map area, west of Johnson Lake, the basalts are generally chloritized, fine grained and massive, and locally intercalated with plagioclase-phyric basalts. Structural deformation of the basalts occurs at several localities; one is west of Rib Lake where the rocks are sheared, heavily epidotized and intruded by numerous quartz veins and granitic dikes.

In thin section these rocks generally indicate a carbonatized and altered mineral assemblage with felty recrystallized textures. Late biotite growth in one sample indicates a possible F_2 fabric, which also crenulated some of the earlier alteration minerals. Chlorites are generally magnesium-rich and tend to indicate a more magnesium-rich than iron-rich protolith. In another sample, similar features are exhibited by crenulated and nematoblastic actinolite.

In the Chopin Lake area most of the metabasalts mainly consist of pillowed flows with well-developed selvages and hyaloclastic interpillow material. Commonly the pillows have a dimension of 10 by 20 cm. Veinlets infilled with calcite and iron carbonate occur together with locally abundant magnetite, chlorite and epidote. Other types of pillowed flows are characterized by some very large pillows (2 by 1 m).

Thin sections of the pillowed flows exhibit both granoblastic and intersertal plagioclase and epidote intergrowth which is a product of retrograde metamorphism and pervasive carbonate alteration. The magnesium-rich compositions of the ferromagnesian minerals and the abundance of magnetite from the possible breakdown of olivine during alteration suggest a possible komatiitic basalt origin.

Plagioclase-phyric basalts (map unit 1d) are another type of mafic metavolcanic rock common in the Chopin-Borden lakes area. The flows are 2 m thick and commonly contain 10% plagioclase feldspar phenocrysts. Field relations indicate that they are definitely not intrusive rocks and exhibit flow features and conformable contacts with nearby pillowed mafic flows (Photo 1). Vesicles, although rare, also occur. In thin section the feldspars occur as phenocrysts up to 0.15 mm long. Vesicles are infilled by quartz and overgrown by a later biotite fabric. A late very low grade retrograde meta-

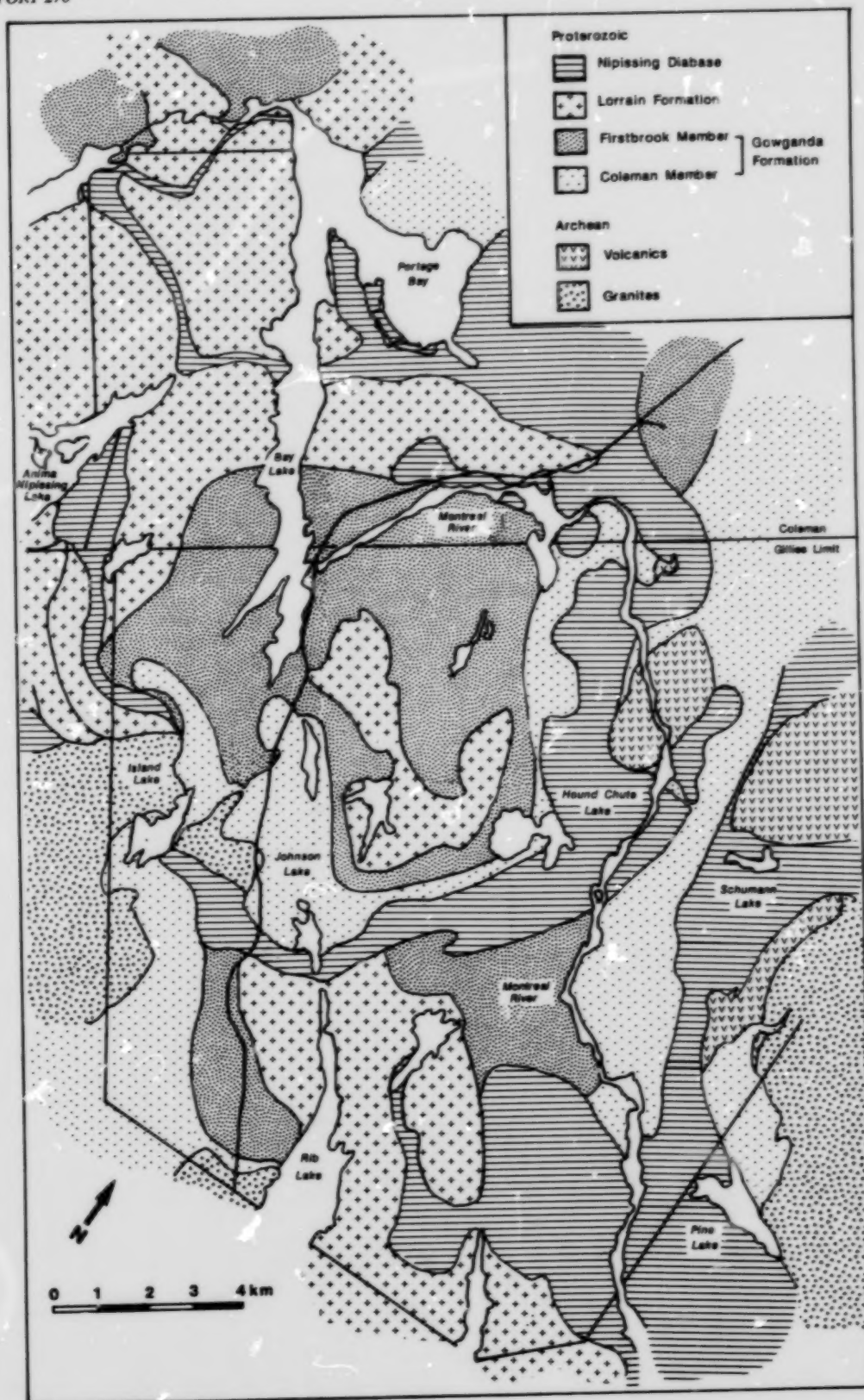


Figure 2. General geology of the Bay Lake area, District of Timiskaming.

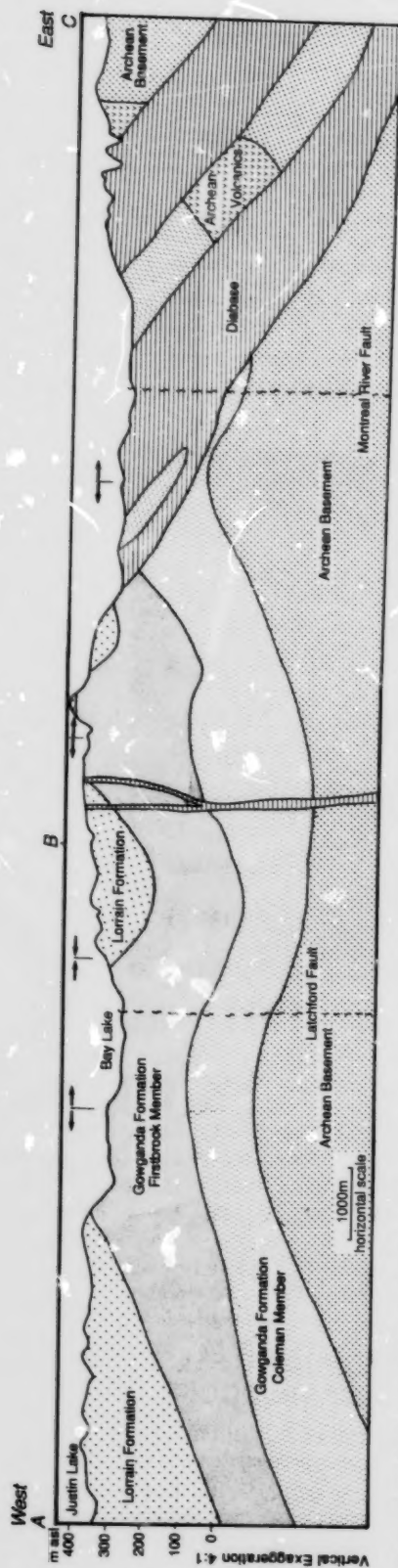


Figure 3. Geological cross section oriented in an east-west direction for the northern part of the Bay Lake area.

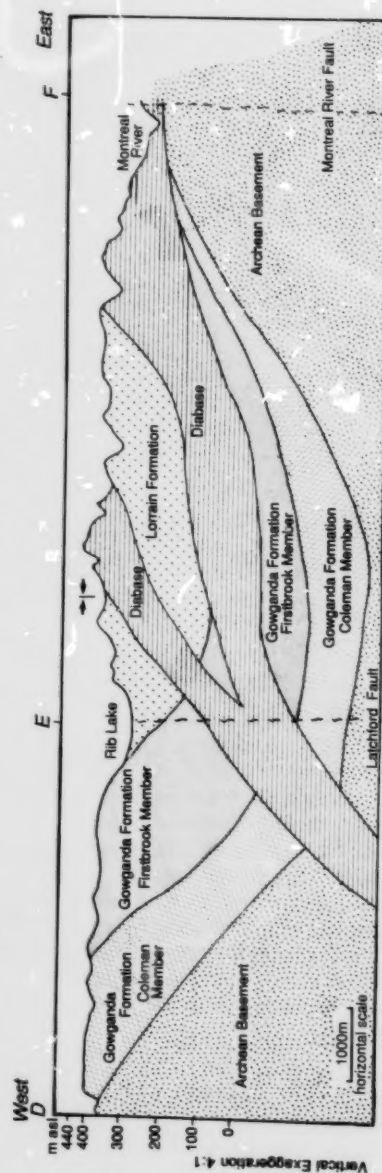


Figure 4. Geological cross section oriented in an east-west direction for the southern part of the Bay Lake area.

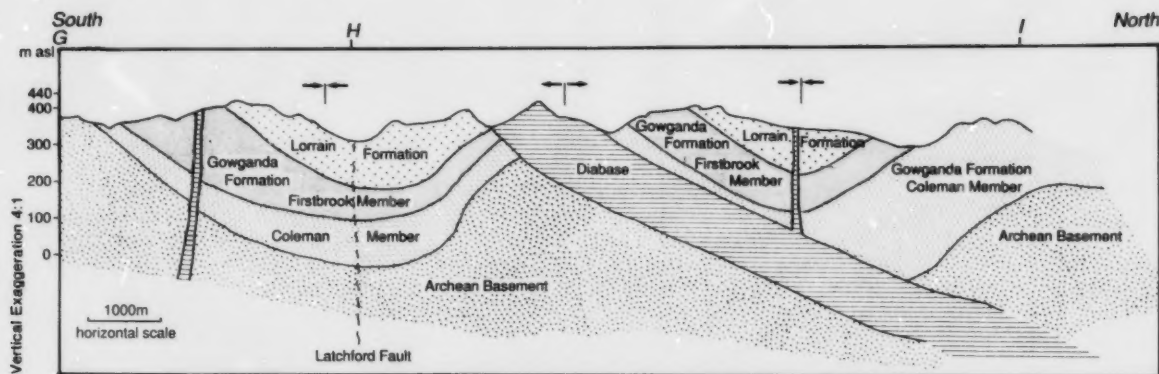


Figure 5. Geological cross section oriented in a north-south direction for the central part of the Bay Lake area.



Photo 1. Archean metavolcanics: pillowed komatiitic basalts overlain by plagioclase-phyric andesites.

morphic assemblage is indicated by the presence of prehnite in some of the amygdules.

Amygdaloidal and variolitic basalts (map unit 1c) are not common but occur at several localities. In the Rib Lake area, highly sheared and altered amygdaloidal basalts are locally intruded and cut by granite dikes. Variolitic basalts occur in the Chopin-Borden lakes area, commonly intercalated with fine-grained vesicular basalts. In thin section the amygdules are up to 1 mm in size and are now infilled by polygonal grains of plagioclase feldspar and overgrown by actinolite. Plagioclase is altered to albite with a radiating habit and felty nematoblastic texture.

Minor quantities of tuffs and debris flow material are intercalated within the mafic metavolcanic sequence at several localities. Near Rib Lake a sheared and crenulated mafic schist mainly consists of a chlorite and biotite matrix with only a few silicious lapilli frag-

ments. This probably represents a mafic tuff. Debris flows and tuffs are also located within mafic volcanics east of Borden Lake. They have similar characteristics to the rocks mentioned above. This unit exhibits some crude bedding in a matrix-supported chloritic ash material hosting some angular mafic and felsic volcanic fragments. The thickness of the unit is estimated as 1 to 3 m.

In thin section the rocks resemble tuffs with large relict plagioclase phenocrysts and minor quartz phenocrysts.

INTERMEDIATE TO FELSIC METAVOLCANIC ROCKS

The petrography of the main rock types are summarized in Table 3. A microscopic description is given below.

Dacite (map unit 2a) is the most common rock type. One of the areas in which it occurs is west of Borden Lake in the northeast corner of the map area. The dacite

Table 1. Table of lithologic units for the Bay Lake area.

PHANEROZOIC**CENOZOIC****QUATERNARY****PLEISTOCENE AND RECENT**

Sand, gravel, clay and swamp deposits

UNCONFORMITY

PRECAMBRIAN**MIDDLE PROTEROZOIC****Lamprophyre Dikes and Diatreme Breccia**

Lamprophyre dikes, Lake Temagami-type diatreme breccia

Olivine Diabase Dikes (Sudbury Swarm)

Fine-grained (chilled), coarse-grained and plagioclase porphyritic olivine diabase

INTRUSIVE CONTACT

EARLY PROTEROZOIC**Mafic Intrusive Rocks****Nipissing Diabase**

Gabbro, hypersthene gabbro, quartz gabbro, leucogabbro, varied textured gabbro, granophyre, sheared and/or hydrothermally altered gabbro

INTRUSIVE CONTACT

HURONIAN SUPERGROUP**Cobalt Group****Lorrain Formation**

Arkose, shaly mudstone, contact metamorphic rocks

CONFORMABLE CONTACT

Gowganda Formation**Firstbrook Member**

Siltstone, mudstone, arenite; contact metamorphic rocks; tectonically brecciated sediments

CONFORMABLE CONTACT

Coleman Member

Basal (regolithic) conglomerate; clast-supported, massive conglomerate; matrix-supported conglomerate; pebbly wacke and lesser arenite; shaly mudstone; sheared and tectonically brecciated sediments

UNCONFORMITY

ARCHEAN**Felsic to Intermediate Plutonic Rocks**

Mafic diorite and minor quartz diorite; tonalite; granodiorite; granite

INTRUSIVE CONTACT

Metavolcanic Rocks**Intermediate to Felsic Metavolcanic Rocks**

Dacite; rhyolite; lapillistone tuffs and pyroclastic flows

Mafic to Intermediate Metavolcanic Rocks

Amphibolite; basalt; pillowed basalt; plagioclase-phyric basalt; variolitic basalt; andesite; minor sedimentary and/or pyroclastic debris flows

Table 2. Petrography of Archean mafic to intermediate metavolcanic rocks.

Map Unit	1a	1b, c	1d, e
Field Name	amphibolite	metabasalt	metabasalt (plagioclase-phyric)
Macroscopic Description			
Colour: fresh weathered	light grey, green dark grey, green	light grey, green dark grey, green	light grey, green dark grey, green
Grain size (mm)	very fine grained (0.5-1.5)	very fine grained (0.5-1.5)	very fine grained (0.5-1.5)
Fragment size(mm) shape		pillows; where present up to 40x20 cm	
Texture	even textured granoblastic	weakly schistose	nematoblastic
Remarks		intercalated	intercalated with pillowed flows
Microscopic Description			
Mode (estimated %)	n = 4	n = 6	n = 2
Plagioclase	0-30	10-20	20-30
Actinolite	0-70	0-55	0-65
Chlorite	0-20	10-15	
Hornblende	0-60		
Orthopyroxene			
Biotite		0-10	0-20
Epidote	0-20	0-20	0-10
Muscovite	10-20	5-20	0-30
Quartz	5-30	0-5	0-5
Prehnite			0-10
Serpentine	0-10		
Carbonate	0-5	3-40	
Titanite		0-3	
Opakes (minerals)	0-5 pyrite	5-10 pyrite	3 magnetite
Location of type sample:	4001D*	0200	2290
Easting	590850	602650	603380
Northing	5234900	5241340	5235820
Texture	granoblastic	schistose	amygdaloidal
Remarks	actinolite defines schistosity	chlorite and actinolite	albite and biotite alteration products

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-4001D.

flows are fine grained with hornblende phenocrysts and with minor quartz eyes and a characteristic light buff-pink weathered surface and a light grey fresh surface. To the east of Borden Lake the dacites are more foliated and exhibit some pyrite gossan and late-stage silicification. In the area to the east of Island Lake, the dacites are slightly porphyritic and cut by granodiorite veinlets. Nearby flows are cut by quartz veinlets and also contain 10 to 25% vesicles infilled with quartz.

In some thin sections granoblastic textures are common. Other less recrystallized samples have pyroclastic textures. The occurrence of hornblende as primary phenocrysts is an indication of the calc-alkaline nature of the parent magma.

Rhyolites (map unit 2b) are less common but characteristically contain 10% blue quartz eyes (< 1 mm in diameter) in an aphanitic matrix with light buff-grey weathered surfaces and medium to dark grey fresh surfaces. Pyrite and chalcopyrite occur in some of the fractures. The rocks are generally siliceous and massive with few flow features. The rhyolites are intercalated with other intermediate to felsic volcanic rocks and presumably represent proximal vent facies rocks.

In thin section rock fragments and broken and corroded crystals occur within a feldspar and quartz matrix which has a grain size of 0.04 mm. Such features indicate a pyroclastic origin for at least some of the rhyolites.

Table 3. Petrography of the Archean intermediate to felsic metavolcanic rocks.

Map Unit	2a	2b	2c
Field Name	dacite	rhyolite	lapillistone or pyroclastic flows
Macroscopic Description			
Colour: fresh weathered	light grey light buff-pink	medium to dark grey light buff-grey	light buff-grey light buff-grey
Grain size (mm)	very fine grained (0.1-0.3)	very fine grained (0.1-0.3)	fine grained (1-2.5)
Fragment size(mm) shape	flows and minor tuffs (0.08-0.12)	flows and minor tuffs (0.08-0.12)	tuffs and pyroclastic flows (1-20)
Texture	massive	massive	
Remarks	locally silicified and some gossan	locally silicified and some gossan	
Microscopic Description			
Mode (estimated %)	n = 2	n = 1	n = 2
Plagioclase	45	60	25-35
Chlorite	5	5	0-5
Hornblende	20		0-20
Epidote	5		5-10
Quartz	20-30	30	30
Carbonate	5		1
Titanite	1		
Opakes (minerals)		5 pyrite	1-5 magnetite
Location of type sample:			
Easting	0330* 590950	0410 601880	0419B 602310
Northing	5233600	5238650	5238550
Texture	clastic to pyroclastic	clastic to pyroclastic	
Remarks	presence of primary hornblende is indicative of calc-alkalic affinity	hornblende present in some samples with some porphyritic textures	some hornblende and typical pyroclastic features except homogeneous pyroclastic flows; good target for massive sulphide mineralization

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0330.

Pyroclastic rocks are also part of the intermediate to felsic suite of metavolcanic rocks. Located to the east of Borden Lake are some fairly homogeneous lapillistone or lapilli pyroclastic flows (Photo 2). The ash matrix contains numerous 1 to 2 cm lapilli-sized clasts. The rocks are very siliceous with a probable original composition of dacite followed by later silicification. Also intercalated with the lapilli tuff flows is some characteristic debris flow material suggesting episodic deposition on a steep subaqueous slope during periodic volcanism. Sulphides are common in the pyroclastic rocks and occur as primary sulphide fragments. This, together with the chloritized and hydrothermally altered nature of the rocks, indicates a good target for massive sulphides.

Textures in thin section are pyroclastic to clastic in nature with lapilli-sized 2 mm fragments set in an ash matrix of 0.02 mm sized quartz and feldspar. Bedding is weakly defined and suggests a possible flow rather than

an air-fall or waterlain tuff. In one of the samples the plagioclase composition is albite. Primary hornblende occurs as phenocrysts.

PETROCHEMISTRY OF THE METAVOLCANIC ROCKS

Samples of 12 Archean metavolcanic rocks were collected for whole rock analyses provided by the Geoscience Laboratories Section, Ontario Geological Survey, Toronto. Tables 4 and 5 list the mafic to intermediate and intermediate to felsic metavolcanics, respectively. Also included for comparative purposes are analyses of a Nipissing diabase granophyre (Sample No. 7) and a sample of chilled Nipissing diabase (Sample No. 5). Locations for all the samples are given in Figure 6.

The main purpose of the analyses is to determine the geochemical affinities of the metavolcanics recog-

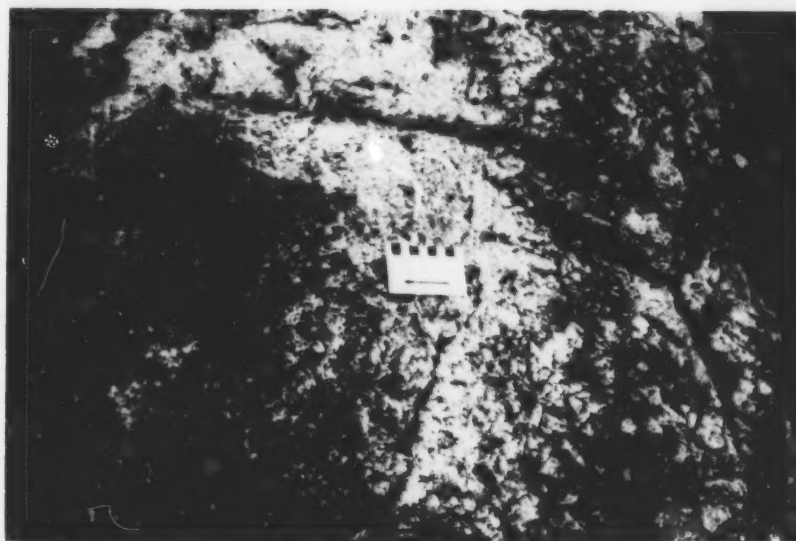


Photo 2. Archean metavolcanics: felsic metavolcanics-lapillistone pyroclastic flow.

nized in the field. The analyses are illustrated on several plots commonly applied to volcanic rocks, namely a cation plot (Jensen 1976; Figure 7), and of a standard AFM weight percent diagram (Irvine and Baragar 1971; Figure 8). In these figures approximately half of the mafic volcanic samples (Sample Nos. 1 to 6) plot in the calc-alkalic field. The other half are high magnesium tholeiite (Sample No. 6), basaltic komatiite (Sample No. 1), or ultramafic komatiite (Sample No. 2). The felsic volcanic samples (Sample Nos. 8 to 13) mainly plot in the calc-alkalic field with the exception of Sample No. 9 which is a tholeiitic andesite-dacite. Also note that the Nipissing diabase granophyre sample (Sample No. 7) is distinctly more alumina- and alkali-rich than any of the felsic volcanic samples. In fact, chemical differences between the granophyre and felsic volcanics make a similar origin for the two unlikely. The chilled Nipissing diabase sample, however, has a composition similar to the plagioclase-phyric andesite flows.

The spatial distribution of rock types indicates the presence of a basal unit of pillowed komatiitic basalts overlain and locally intercalated with calc-alkalic plagioclase-phyric andesite flows overlain by calc-alkalic pyroclastic rocks in the northeast corner of the map area. In the central portion some minor tholeiitic migmatized basalts are intercalated with calc-alkalic flows and pyroclastic rocks. Along the southern margin of the map area there is a definite suite of volcanic to synvolcanic ultramafic rocks with a komatiitic chemical affinity. Similar rocks occur to the west in the nearby Whitney Lake area (Thomson 1964) and in the Mountain Lake area (Born and Burbidge, in press).

Several binary plots illustrate elemental differences between the mafic and felsic metavolcanics. Trends in the diagrams describe the geochemical characteristics of each group. The plot of TiO_2 versus MgO

(Figure 9) shows a fairly good separation of Sample Nos. 1 and 2 (komatiitic affinity) from the rest of the predominantly calc-alkalic group. Sample Nos. 1 and 2 have much higher values of MgO (12 to 27%) and lower values of TiO_2 (0.4 to 0.5%). Sample Nos. 6 and 9 are the only ones with typical tholeiitic values of TiO_2 (1.4%) and MgO (2 to 6%). The rest of the samples are of the calc-alkalic suite and indicate a narrow range of TiO_2 (0.2 to 1.0%) and MgO (1 to 5%). Thus the diagram separates the samples into three main groups as discussed above. In the TiO_2 versus Cr plot (Figure 10) a similar separation occurs into three main groups with the chromium values of Sample Nos. 1 and 2 much higher (85 to 170 ppm) than the rest of the samples. The Al_2O_3 versus Cr plot (Figure 11) illustrates a distinctive separation of samples with komatiitic affinity (Sample Nos. 1 and 2) from the rest of the samples, which is similar to Figures 8 and 9. Alumina content in these samples ranges from 5 to 12% Al_2O_3 and is much lower than the other samples. In samples from calc-alkalic rocks it ranges from 13 to 18% Al_2O_3 . Figures 12 and 13 are the Al_2O_3 versus $\text{FeO}/(\text{FeO} + \text{MgO})$ and Al_2O_3 versus $\text{MgO}/(\text{FeO} + \text{MgO})$ plots, respectively. Both figures illustrate the higher MgO and lower alumina content of the komatiitic rocks (Sample Nos. 1 and 2) as opposed to the remainder of the mainly calc-alkalic suite of rocks.

Previous local geochemical investigations have been undertaken by Smyk et al. (in press) in neighbouring Banting and Best townships and indicate the predominance of tholeiitic basalts with some lesser calc-alkalic basalts and andesites. Volcanic rocks in adjacent Brigstocke and Kittson townships are composed mainly of a tholeiitic mafic volcanic suite intercalated with some minor komatiitic basalts (Born and Burbidge, in press). In Cassels Township the geochemistry of the volcanic rocks indicates a basal tholeiitic unit overlain by

Table 4. Chemical analyses and normative mineralogy of Archean mafic to intermediate metavolcanic rocks.

Reference No. Sample No.	1 0200*	2 0281	3 0288	4 2230	5 2290	6 0302
Major Elements (wt%)						
SiO ₂	50.40	41.00	59.40	55.60	55.30	48.40
Al ₂ O ₃	11.70	5.33	15.60	17.20	17.10	13.40
Fe ₂ O ₃	1.98	5.85	2.29	1.70	2.10	5.57
FeO	6.72	7.52	5.06	5.26	5.19	7.32
MgO	12.80	26.60	3.36	5.18	4.08	5.62
CaO	7.13	1.62	6.37	5.24	5.83	7.00
Na ₂ O	2.89	00.00	3.39	5.08	5.19	3.50
K ₂ O	0.89	0.13	1.09	1.77	1.88	0.62
TiO ₂	0.51	0.31	1.05	0.58	0.59	1.45
P ₂ O ₅	0.42	0.05	0.12	0.14	0.14	0.15
MnO	0.24	0.19	0.14	0.11	0.10	0.28
CO ₂	0.14	0.52	0.35	0.06	0.09	1.70
S	0.11	0.04	0.03	0.01	0.04	0.55
H ₂ O ⁺	3.72	8.68	0.99	1.70	1.73	2.96
H ₂ O ⁻	0.12	0.53	00.00	0.08	0.11	0.15
TOTAL	99.80	98.40	99.20	99.70	99.50	98.70
LOI	3.40	9.00	0.70	1.20	1.20	3.20
sg	2.89	2.78	2.83	2.82	2.86	2.88
METHOD						
	0200	0281	0288	2230	2290	0302
Trace Elements (ppm)						
Ag AA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
As AA	20	2	1	N.D.	2	2.50
Bi AA	0.30	N.D.	0.20	N.D.	2	1
Co AA	48	98	27	23	21	42
Cr AA	960	1630	51	120	14	85
Cu AA	63		32	35	33	62
Ni AA	395	1970	43	117	111	43
Pb AA	30	N.D.	N.D.	N.D.	N.D.	N.D.
Zn AA	350	150	80	76	98	155
B ICP/OES				15	9	
Be ICP/OES	4	N.D.	1	N.D.	N.D.	2
Co ICP/OES				24	23	
Cu ICP/OES				32	30	
Mo ICP/OES	N.D.	N.D.	N.D.	N.D.	N.D.	20
Ni ICP/OES				111	108	
Sc ICP/OES	8	9	24	15	16	54
Sr ICP/OES	271	23	180	174	171	151
V ICP/OES	147	69	181	118	119	361
Y ICP/OES	15	N.D.	18	16	16	27
Zn ICP/OES				59	80	
Hg AA (ppb)	11	8	5			8
Au AA "	N.D.	N.D.	N.D.	2	N.D.	N.D.
Pt AA "	4	1	N.D.			N.D.
Pd AA "	5	1	N.D.			N.D.

Abbreviations: AA: Atomic Absorption; ICP: Induced Coupled Plasma; OES: Optical Emission Spectrometry; N.D.: not detected

calc-alkalic pyroclastics overlain by an upper tholeiitic unit within the Lake Tetapaga syncline (Born 1989).

Intermediate to Felsic Plutonic Rocks

The granitic rocks were classified according to Streckeisen (1976). A heterogeneous assemblage of plutonic rocks occurs in the Bay Lake area and is listed in Table 6. Foliated diorite, granodiorite and tonalite intrude the metavolcanic rocks and underlie only a small area in the southwest part of the map area. These rocks are the eastern extension of an intrusive and/or migmatite basement complex described by Born and Burbidge (in

press) in Brigstocke Township. In general most outcrops typically have transitional internal contacts between the various rock types mentioned above and suggest homogenization during partial melting. As in Brigstocke Township migmatitic structures such as mobilize sweats and veinlets occur but are generally not very abundant.

Diorites are commonly weakly foliated and hypidiomorphic granular. They are typically mafic with 30% amphibole. Others exhibit plagioclase and amphibole clots and sweats and veins typical of migmatitic textures. However, near Island Lake the mafic diorite exhibits some porphyritic plagioclase textures and is cut by sev-

TABLE 4. (Continued)

CIPW Norms		1	2	3	4	5	6
Reference No.							
Sample No.		0200	0281	0288	2230	2290	0302
APIT	apatite	1.0397	0.1343	0.2904	0.3389	0.3401	0.3818
PYRT	pyrite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ILMN	ilmenite	1.0123	0.6676	2.0376	1.1256	1.1493	2.9596
ORTH	orthoclase	5.4967	0.8710	6.5813	10.6881	11.3944	3.9375
ALBT	albite	25.5585	0.0000	29.3095	43.9255	45.0429	31.8289
ACMT	acmite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ANRT	anorthite	17.0605	8.7422	24.6551	19.3147	18.2668	20.4426
SPHN	sphene	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUTL	rutile	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MGNT	magnetite	3.0004	2.9756	3.3925	2.5187	3.1080	4.5968
HEMT	hematite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DIOP	diopside	10.6451	0.0000	3.4563	3.4076	5.3333	7.1135
HEDN	hedenbergite	3.0009	0.0000	2.1339	1.7274	3.2176	5.9636
WOLL	wollastonite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ENST	enstatite	16.7189	40.6868	6.9479	8.3880	5.1160	11.2596
FERS	ferrosilite	5.4063	11.5649	4.9205	4.8773	3.5405	10.8278
QRTZ	quartz	0.0000	0.0000	16.2830	0.0000	0.0000	0.0000
FORS	forsterite	8.1737	24.1259	0.0000	2.2531	1.9856	0.3400
FAYA	fayalite	2.9128	7.5575	0.0000	1.4438	1.5143	0.3603
PVSK	perovskite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NEPH	nepheline	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LEUC	leucite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DICA	dicalcium silicate	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
KALP	kaliophilite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CNDM	corundum	0.0000	2.6800	0.0000	0.0000	0.0000	0.0000
CALC	calcite	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NPLG	normative plagioclase index	40.0303	100.0000	45.6875	30.5418	28.8531	39.1085
FEMG	FeO + MgO	0.4135	0.9100	0.1311	0.1894	0.1585	0.2595
RMG	MgO/FeO + MgO	0.8025	0.8222	0.6498	0.6933	0.6550	0.5774
RFE	FeO/FeO + MgO	0.1975	0.1778	0.3502	0.3067	0.3450	0.4226
CI	colour index	50.8705	87.5783	22.8888	25.7416	24.9646	43.4213

1. pillowed basalt

2. ultramafic to mafic synvolcanic intrusive rock

3. plagioclase-phyric basalt-andesite

4. silicified and pillowed basalt-andesite

5. fine-grained chilled phase of Nipissing diabase

6. basalt with some migmatitic swells

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0200.

eral 1 to 2 cm migmatitic mobilize swells. Local volcanic xenoliths occur.

Archean mafic diorites are commonly difficult to distinguish from Early Proterozoic Nipissing diabase rocks. The latter, however, shows no migmatitic features and has a typical nonfoliated nature with common subophitic textures. Plagioclase compositions of greater than An₅₀ are common in these rocks. The diorites are foliated with common blastic deformation and local migmatite veinlets and segregations.

Tonalite is a relatively rare rock type and found in only a few localities in the southwest part of the map area. It is typically mafic with 30% amphiboles and 30% quartz.

Granodiorite is generally coarse grained with 5% biotite and 30% quartz and commonly contains some mafic xenoliths. These are generally subangular to subrounded clasts from 2 to 10 cm in size. Local digestion of some of the clasts has been observed.

Granites occur mainly in the northeast corner of the map area and also intrude the metavolcanic rocks.

The granites are more homogeneous and massive than the other plutonic rocks commonly characterized by a weak foliation. This implies that the granites may represent a Late Archean pluton younger than the rest of the basement complex. In the Chopin Lake area the granites are very coarse grained, massive and homogeneous with few mafic minerals, and some local pegmatites. Both carbonate and hematite alteration occurs locally. Contrary to the other plutonic rocks there are no extensive xenolithic zones within the granites. This large granite pluton has been referred to in the past as the "Lorrain granite" by various workers including Lovell and de Grijps (1976) and Thomson (1960, 1961, 1963a, 1963b, 1963c, 1964, 1968).

Another minor type of Archean rocks are mafic diabase dikes. They range in width from 10 to 30 cm and are located in a few outcrops cutting mafic diorite, granodiorite and fine-grained mafic volcanic rocks.

Chemical analyses and norms for some representative rocks are presented in Table 7. Sample Nos. 14 and 15 represent granite and mafic diorite, respectively. Sample No. 20 represents an Archean regolith of a gra-

Table 5. Chemical analyses and normative mineralogy of Archean intermediate to felsic metavolcanic rocks.

Reference No.	7	8	9	10	11	12	13
Sample No.	0056*	0306	0307	0398	0423	0410	0419
Major Elements (wt%)							
SiO ₂	72.50	59.60	53.40	72.70	70.40	62.50	57.80
Al ₂ O ₃	17.50	17.20	17.00	13.00	14.40	17.50	13.90
Fe ₂ O ₃	0.41	1.65	3.88	1.86	0.94	2.76	2.34
FeO	0.60	4.79	6.59	2.00	2.60	3.35	6.39
MgO	0.16	2.62	2.72	1.02	1.52	2.03	4.09
CaO	1.05	4.67	6.57	1.03	0.20	0.75	2.53
Na ₂ O	4.01	3.51	3.15	4.90	6.76	2.89	3.48
K ₂ O	2.81	1.37	1.32	1.30	0.14	2.96	2.89
TiO ₂	0.05	0.64	1.39	0.25	0.42	0.57	0.98
P ₂ O ₅	00.00	0.18	0.23	0.05	0.09	0.13	0.25
MnO	0.02	0.10	0.17	0.03	0.02	0.05	0.10
CO ₂	0.39	0.19	0.29	0.55	0.26	0.21	0.20
S	0.01	0.05	0.45	0.18	0.02	0.03	0.37
H ₂ O ⁺	0.57	2.23	2.33	1.16	1.34	2.87	3.00
H ₂ O ⁻	00.00	0.15	0.17	0.13	0.08	00.00	0.40
TOTAL	100.10	99.00	99.60	100.20	99.20	98.80	98.70
LOI	0.60	1.80	1.20	1.40	1.40	2.70	3.00
sg	2.64	2.78	2.89	2.69	2.65	02.69	00.00
METHOD							
	0056	0306	0307	0398	0423	0410	0419
Trace Elements (ppm)							
Ag	AA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
As	AA	1	12	1.50	2	3	53
Bi	AA	N.D.	0.30	0.80			
Co	AA	N.D.	20	33	11	8	17
Cr	AA	N.D.	35	N.D.	10	10	100
Cu	AA	19	47	63	20	9	33
Ni	AA	N.D.	40	34	11	10	43
Pb	AA	12	10	N.D.	13	N.D.	N.D.
Zn	AA	15	88	145	17	15	51
B	ICP/OES				16	3	45
Be	ICP/OES	1	1	2	2	N.D.	2
Co	ICP/OES				11	8	16
Cu	ICP/OES				18	7	29
Mo	ICP/OES	16	12	13	N.D.	N.D.	N.D.
Ni	ICP/OES				10	9	38
Sc	ICP/OES	2	20	28	5	7	12
Sr	ICP/OES	79	281	242	85	30	62
V	ICP/OES	N.D.	75	224	14	37	91
Y	ICP/OES	15	22	26	24	12	13
Zn	ICP/OES				12	11	37
Hg	AA (ppb)	N.D.	6	6			
Au	AA	N.D.	N.D.	N.D.	N.D.	N.D.	6
Pt	AA	N.D.	N.D.	N.D.			
Pd	AA	N.D.	N.D.	N.D.			

Abbreviations: AA: Atomic Absorption; ICP: Induced Coupled Plasma; OES: Optical Emission Spectrometry; N.D.: not detected

nitic composition. Norms from these samples are plotted on a QAP (quartz-alkali feldspar-plagioclase) diagram (Figure 14). It illustrates that the norms are a close approximation to the field identification. Also it substantiates distinct compositional differences of the various rocks in the plutonic suite. Thus, this geochemical evidence supports most field classifications and relationships. The location of Sample No. 20 in Figure 14 also indicates the altered geochemical nature of the granitic regolith. Most of the alkalis have been removed and as a result the sample plots near the apex of the QAP diagram.

EARLY TO MIDDLE PROTEROZOIC ROCKS

Early Proterozoic rocks of the Huronian Supergroup, namely the sedimentary rocks of the Gowganda and overlying Lorrain Formations, underlie large parts of the map area. The Gowganda Formation consists of a lower unit, the Coleman Member, and an upper unit, the Firstbrook Member.

Rocks of the Coleman Member locally have a maximum thickness of 430 m. They occur as a blanket which

Table 5. (Continued)

CIPW Norms							
Reference No.	7	8	9	10	11	12	13
Sample No.	0056	0306	0307	0398	0423	0419	0419
APTT	0.0000	0.4426	0.5656	0.1207	0.2187	0.3227	0.6250
PYKT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ILMN	0.0958	1.2618	2.7407	0.4839	0.8182	1.1345	1.9644
ORTH	16.7542	8.4041	8.0982	7.8285	0.8486	18.3308	18.0241
ALBT	34.2362	30.8322	27.6725	42.2530	58.6740	25.6279	31.0784
ACMT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ANRT	5.2558	22.8298	29.4308	4.8744	0.4146	3.0092	11.5230
SPHN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUTL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MGNT	0.5998	2.4835	4.3503	2.5857	1.3980	3.1453	3.5808
HEMT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DIOP	0.0000	0.0000	1.0800	0.0000	0.0000	0.0000	0.0000
HEDN	0.0000	0.0000	1.3024	0.0000	0.0000	0.0000	0.0000
WOLL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ENST	0.4021	6.7737	6.5323	2.5888	3.8830	5.2984	10.7506
FERS	0.7241	6.8119	9.0357	2.0907	3.4275	4.9605	8.8322
QRTZ	35.9261	18.2166	9.2061	35.3645	27.2663	29.2814	12.5330
FORS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FAYA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PVSK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NEPH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LEUC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DICA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
KALP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CNDM	6.0062	1.9548	0.0000	1.8129	3.0562	8.8970	1.1037
CALC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NPLG	13.3086	42.5437	51.5396	10.3430	0.7017	10.5081	27.0484
FEMG	0.0095	0.1191	0.1438	0.0416	0.0647	0.0904	0.1740
RMG	0.4218	0.5665	0.4872	0.6194	0.5982	0.5840	0.6153
RFE	0.5782	0.4335	0.5128	0.3806	0.4018	0.4160	0.3847
CI	1.8218	17.3309	25.0414	7.7490	9.5267	14.5387	25.1279

7. rhyolite feeder dike; post-Archean?, probably Nipissing aged granophyre

8. fragmental dacite; Archean lapilli tuff

9. andesite-dacite flows, all vesicular; Archean

10. rhyolite, with quartz eyes; Archean

11. rhyolite, with quartz eyes and amphibole phenocrysts; Archean

12. dacite flows, with quartz eyes and amphibole phenocrysts; Archean

13. dacite pyroclastic flows, with some sulphide fragments

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 83PJB-0056.

Note: see Table 4 for explanation of CIPW Norm abbreviations.

unconformably drapes the Archean basement rocks. The Coleman member consists of a local basal conglomerate, and both massive and stratified matrix-supported conglomerates, arkoses, pebbly wackes and shaly mudstones.

The Firstbrook Member has a maximum thickness of about 260 m. It consists of a single, coarsening-upwards sequence of laminated mudstones, siltstones and arenites in the lower, middle and upper parts of the member, respectively.

Rocks of the lower Lorrain Formation locally have a maximum thickness of 250 m and underlie much of the southern and northwestern parts of the map area. Locally, they consist of a lower fine-grained arkose overlain by some minor mudstones and an upper coarse-grained arkose.

Early Proterozoic Nipissing diabases form several east-trending sills (500 m thick maximum) which intrude all of the older rock types. Contact metamorphism of

Proterozoic sediments resulted in chlorite spotting and epidotization in arkoses of the Lorrain Formation and shaly mudstones of the Gowganda Formation.

Coarse-grained quartz diabase and hypersthene gabbro are the main rock types in the lower parts of the main diabase sill of the area. Along the lower contact of one of the sills, the diabase is fine grained, epidotized and exhibits characteristic polygonal, columnar jointing. Coarse-grained varied textured gabbro is the main rock type of the upper portions of the sills. Granophyre occurs sporadically along the upper contact of the sill where it is in contact with arkoses of the Lorrain Formation.

The youngest Precambrian rocks in the area are represented by northwest-trending olivine diabase dikes and less prominent lamprophyre dikes.

The grade of regional metamorphism in the area varies from subgreenschist facies in Middle Proterozoic age or younger olivine diabase and lamprophyre dikes, to lower greenschist facies in the Huronian sedimentary

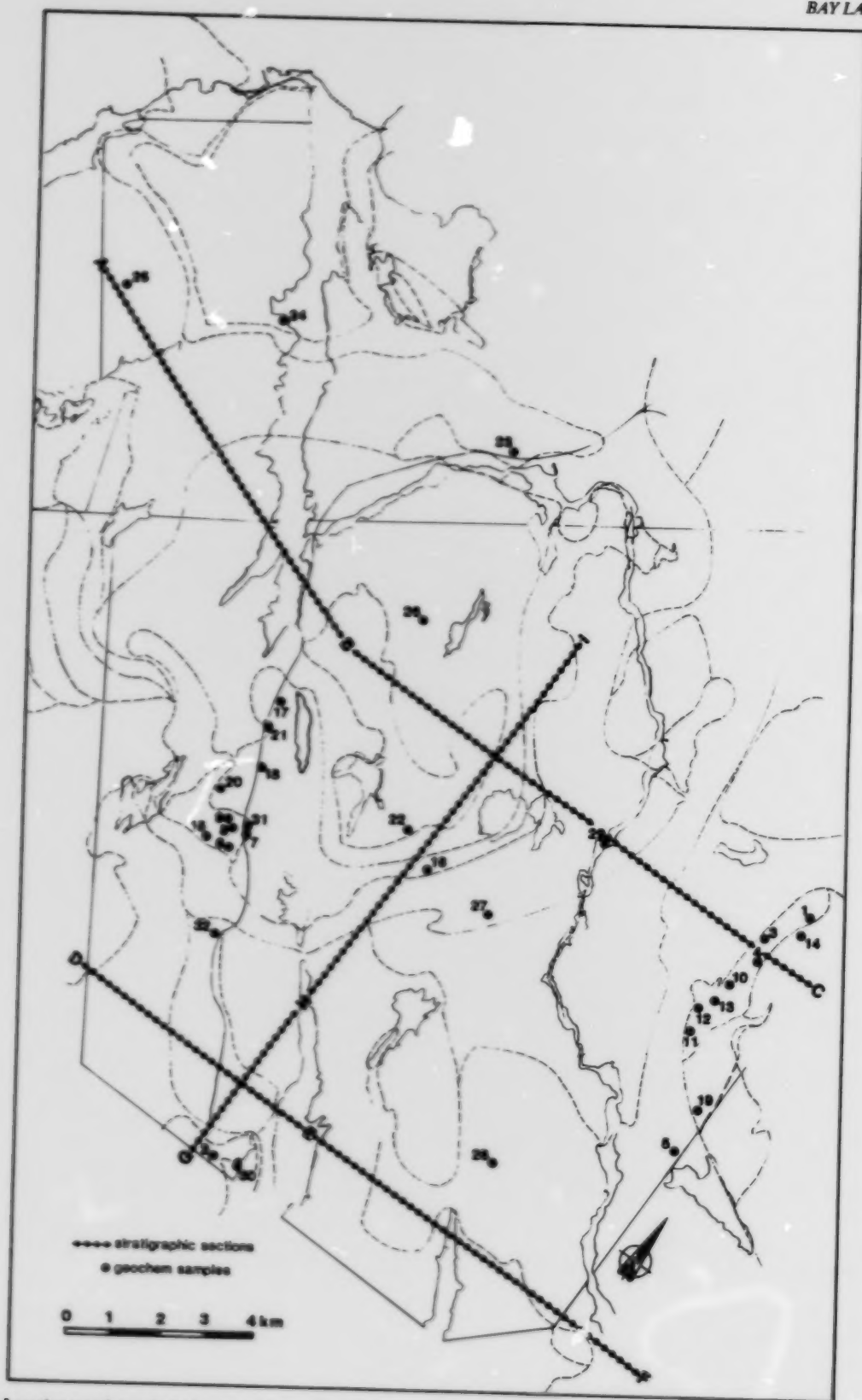


Figure 6. Location map for geological cross sections, composite stratigraphic sections and chemically analyzed samples. Geological boundaries indicated by dashed lines; see Figure 2 for general geology.

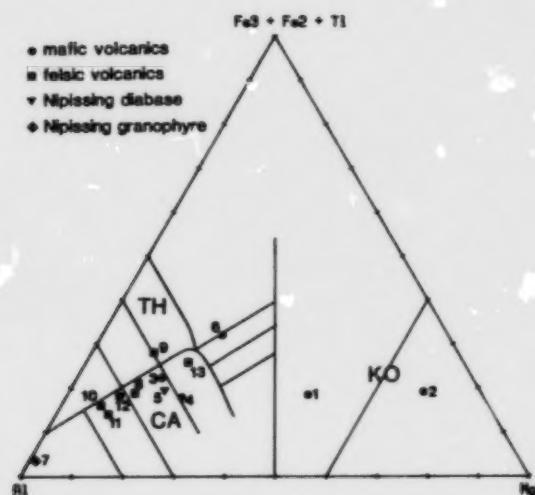


Figure 7. Cation plot (Jensen 1976) for Archean metavolcanic rocks. TH-tholeiitic, CA-calc-alkalic, KO-komatiitic.

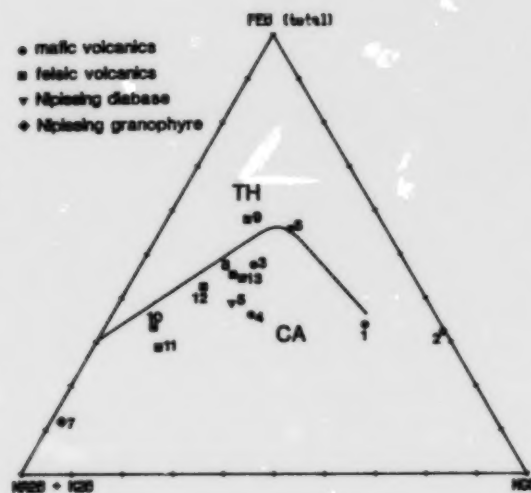


Figure 8. AFM plot for Archean metavolcanic rocks. TH-tholeiitic, CA-calc-alkalic.

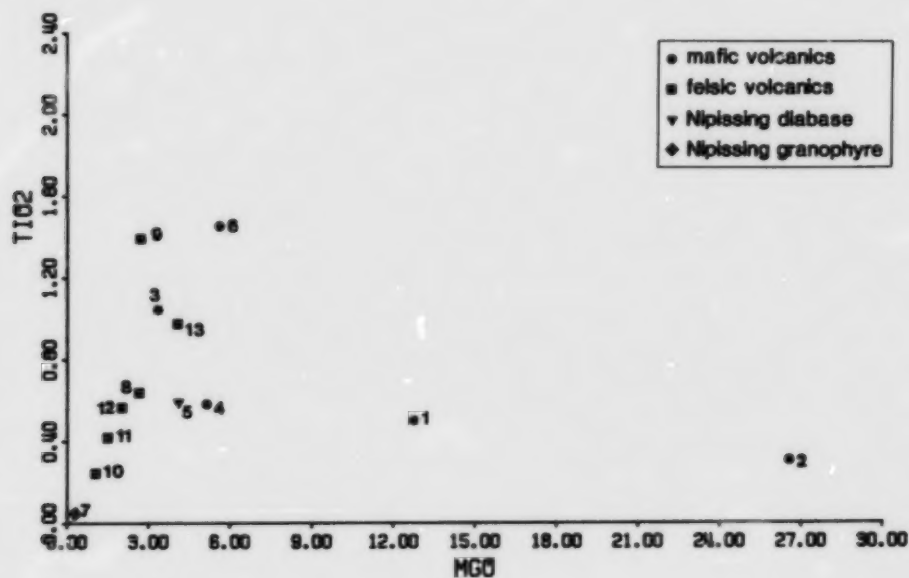


Figure 9. Binary weight percent plot of TiO_2 versus MgO for Archean metavolcanic rocks.

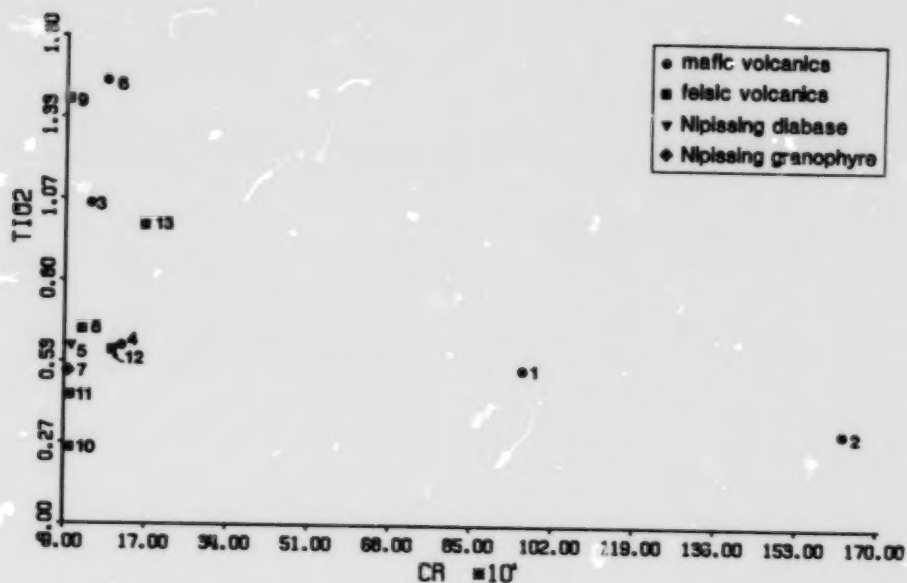


Figure 10. Binary weight percent plot of TiO₂ versus Cr for Archean metavolcanic rocks.

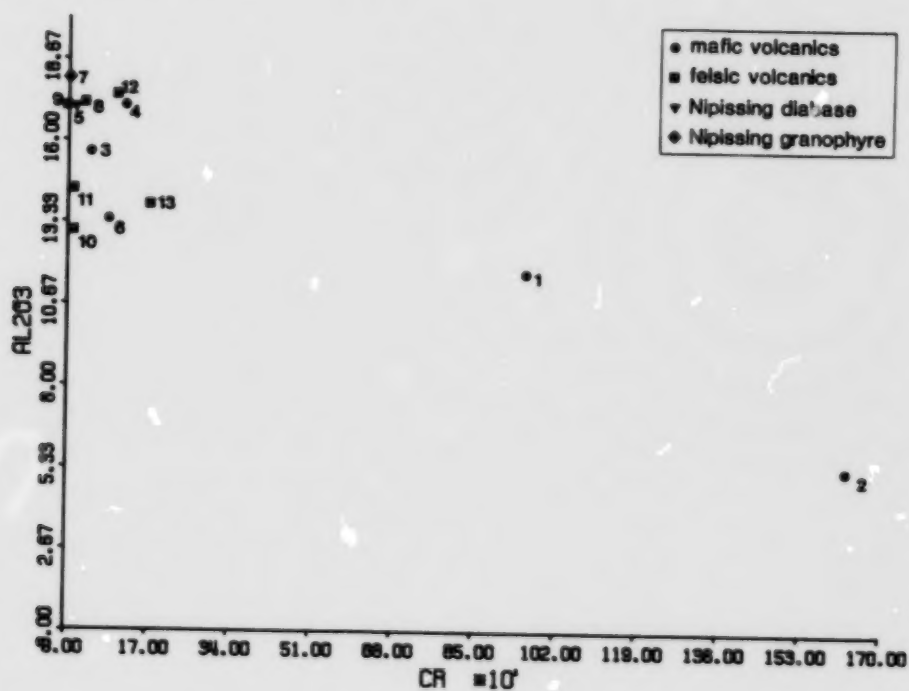


Figure 11. Binary weight percent plot of Al₂O₃ versus Cr for Archean metavolcanic rocks.

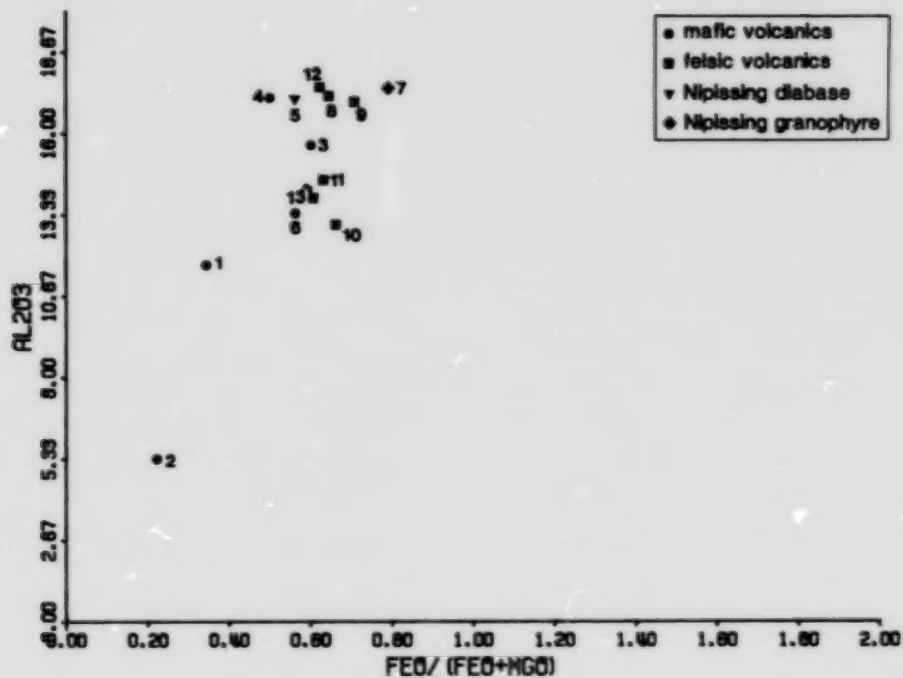


Figure 12. Binary weight percent plot of Al_2O_3 versus $FeO/(FeO + MgO)$ for Archean metavolcanic rocks.

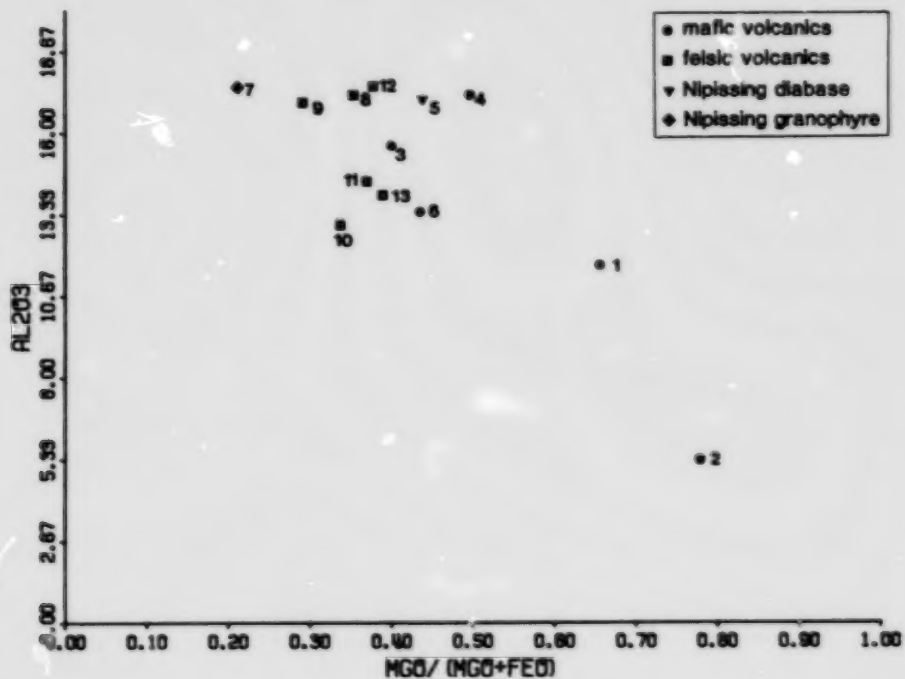


Figure 13. Binary weight percent plot of Al_2O_3 versus $MgO/(MgO + FeO)$ for Archean metavolcanic rocks.

Table 6. Petrography of Archean intermediate to felsic plutonic rocks.

Map Unit	3a	3b	3c	3d
Field Name	mafic diorite	tonalite	granodiorite	granite
Macroscopic Description				
Colour: fresh	dark grey	light grey	light red-pink	red-pink
weathered	light grey	light grey	light buff-pink	red-pink
Grain size (mm)	coarse grained (1-3)	coarse grained (1-3)	coarse grained (1-3)	coarse grained (1-3)
Fragment size(mm) shape				
Texture	massive to foliated	massive to foliated	massive to foliated	massive
Remarks	contacts between rock types gradational and part of migmatite suite			later phase intrusive
Microscopic Description				
Mode (estimated %)	n = 1	n = 1	n = 3	n = 2
Plagioclase	35	40	45-60	10
Microcline			10-20	60
Chlorite	5	5	5	1-5
Hornblende	20			
Biotite				
Epidote	15	5		0-3
Muscovite	15	20		0-3
Quartz	5	25	2-5	1
Carbonate	3		15-20	15-25
Opauques (minerals)	3	3	0-5	
	pyrite	pyrite	3-5	
			pyrite	
Location of type sample:	0350*	0055D	0321	0273
Easting	595200	592400	591160	602760
Northing	5230260	5235700	5236060	5241150
Texture	hypidiomorphic granular	hypidiomorphic granular	hypidiomorphic and some minor mortar textures	hypidiomorphic, some Fe-stained microcline
Remarks	some weak crenulations in some amphiboles	chlorite replaces original ferro-magnesian minerals	oligoclase (An ₂₅), relatively unaltered rock	andesine(An ₃₀), relatively unaltered rock

**All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0350.*

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PIB-0350.

rocks, to amphibolite facies in the Archean metavolcanic and migmatitic and/or metaplutonic rocks.

EARLY PROTEROZOIC

Huronian Supergroup

COBALT GROUP

Early Proterozoic rocks of the Huronian Supergroup, namely the sedimentary rocks of the Gowganda and overlying Lorrain Formations underlie large parts of the map area. The Gowganda Formation consists of a lower unit, the Coleman Member, and an upper unit, the Firstbrook Member.

Subdivisions and descriptions of the individual units are similar to those reported for the adjacent area to the west by Born and Burbidge (in press).

The local stratigraphic section has a maximum thickness of 650 m as illustrated in 3 key stratigraphic sections. Figures 15, 16 and 17 are taken from the 3 corresponding geological cross sections in Figures 4, 5 and 3, respectively. Locations for these sections are given in Figure 6.

Figure 15 represents a fairly complete section of the Gowganda Formation west of Rib Lake with most of the Coleman Member and all of the Firstbrook Member except the lower unit. It also illustrates the Firstbrook Member-Lorrain Formation transition.

Table 7. Chemical analyses and normative mineralogy of Archean intermediate to felsic plutonic rocks.

Reference No. Sample No.	14 0273*	15 0315	20 0322
Major Elements (wt%)			
SiO ₂	71.40	49.80	71.70
Al ₂ O ₃	15.00	15.60	13.70
Fe ₂ O ₃	0.74	5.38	0.68
FeO	0.87	8.39	1.60
MgO	0.57	4.37	0.52
CaO	0.43	6.53	1.82
Na ₂ O	4.08	3.95	5.81
K ₂ O	4.44	1.41	0.55
TiO ₂	0.18	1.57	0.37
P ₂ O ₅	0.07	0.07	0.06
MnO	0.01	0.20	0.06
CO ₂	0.26	0.17	1.26
S	0.01	0.28	0.09
H ₂ O ⁺	0.55	2.26	0.88
H ₂ O ⁻	00.00	0.08	0.07
TOTAL	98.60	100.00	99.20
LOI	0.60	1.70	1.80
sg	2.61	02.83	02.63

METHOD	0273	0315	0322
Trace Elements (ppm)			
Ag AA	N.D.	N.D.	N.D.
As AA	N.D.	22	3
Bi AA	N.D.		
Co AA	N.D.	43	9
Cr AA	12	55	30
Cu AA	10	203	18
Ni AA	N.D.	38	10
Pb AA	N.D.	10	N.D.
Zn AA	12	132	22
B ICP/OES		27	6
Be ICP/OES	6	2	N.D.
Co ICP/OES		44	8
Cu ICP/OES		201	17
Mo ICP/OES	N.D.	N.D.	N.D.
Ni ICP/OES		36	10
Sc ICP/OES	N.D.	24	7
Sr ICP/OES	95	200	89
V ICP/OES	15	518	28
Y ICP/OES	N.D.	12	17
Zn ICP/OES		95	18
Hg AA (ppb)	6		
Au AA "	N.D.	N.D.	4
Pt AA "	N.D.		
Pd AA "	N.D.		

Abbreviations: AA: Atomic Absorption; ICP: Induced Coupled Plasma; OES: Optical Emission Spectrometry; N.D.: not detected

Figure 16 represents a location south of Rib Lake and shows a more compact section than Figure 15. Figure 17 illustrates a section east of Bay Lake and shows the middle Firstbrook Member-Lorrain Formation transition. This section is the only one in which the mudstones of the Lorrain Formation are shown and illustrates their relationship with both overlying and underlying arkoses of the Lorrain Formation and underlying mudstones of the Firstbrook Member.

One of the purposes of the detailed geological work on the sedimentary rocks was to map stratigraphic sec-

Table 7. (Continued)

CIPW Norms Reference No. Sample No.	14 0273	15 0315	20 0322
APTT	0.1695	0.1709	0.1467
PYRT	0.0000	0.0000	0.0000
ILMN	0.3496	3.0728	0.7254
ORTH	26.8301	8.5864	3.3551
ALBT	35.3040	34.4438	50.7511
ACMT	0.0000	0.0000	0.0000
ANRT	1.7138	21.3020	8.9161
SPHN	0.0000	0.0000	0.0000
RUTL	0.0000	0.0000	0.0000
MGNT	1.0972	4.5870	1.0178
HEMT	0.0000	0.0000	0.0000
DIOP	0.0000	4.4931	0.0000
HEDN	0.0000	5.2065	0.0000
WOLL	0.0000	0.0000	0.0000
ENST	1.4517	3.9356	1.3369
FERS	0.7236	5.2313	1.9376
QRTZ	29.4313	0.0000	31.4236
FORS	0.0000	3.6419	0.0000
FAYA	0.0000	5.3350	0.0000
PVSK	0.0000	0.0000	0.0000
NEPH	0.0000	0.0000	0.0000
LEUC	0.0000	0.0000	0.0000
DICA	0.0000	0.0000	0.0000
KALP	0.0000	0.0000	0.0000
CNDM	2.9330	0.0000	0.3937
CALC	0.0000	0.0000	0.0000
NPLG	4.6296	38.2127	14.9431
FEMG	0.0199	0.2247	0.0280
RMG	0.7250	0.4971	0.4755
RFE	0.2750	0.5029	0.5245
CI	3.6220	35.5033	5.0177

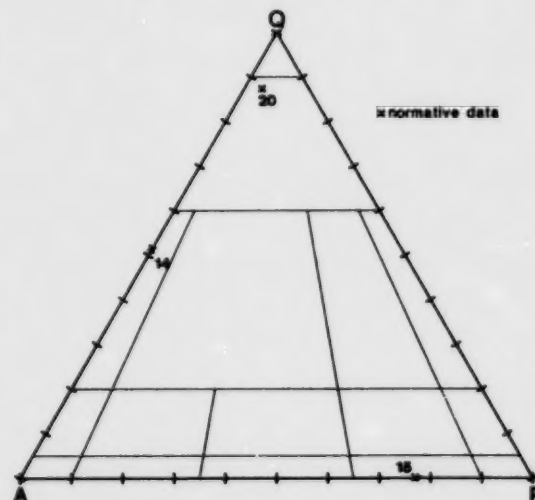
14. Lorrain granite; Chopin Lake area

15. mafic diorite with some sulphides

20. Archean basement regolith below Coleman Member, Gowganda Formation

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0273.

Note: see Table 4 for explanation of CIPW Norm abbreviations.

**Figure 14.** Ternary QAP plot (Streckeisen 1976) of some intermediate to felsic plutonic rocks.

tions and develop facies models. In order to do this the rocks were classified in terms of both rock type and lithofacies, the latter according to a scheme proposed by Miall (1978) which is summarized in Table 8.

Gowganda Formation

The Gowganda Formation consists of a lower unit, the Coleman Member, and an upper unit, the Firstbrook Member.

Rocks of the Coleman Member locally have a maximum thickness of 430 m. They occur as a blanket which unconformably drapes the Archean basement rocks.

The Firstbrook Member has a maximum thickness of about 260 m. It consists of a single, coarsening-upwards sequence of fine-grained rocks (F1 and Fr lithofacies) which include mud, silt and minor very fine sand (Miall 1978; Rust 1978a, 1978b). These sediments overlie the Coleman Member and occur as a northwest-trending unit in the western part of Coleman and Gillies Limit townships.

Rocks of the lower Lorrain Formation locally have a maximum thickness of 650 m and underlie much of the southern and northwestern parts of the map area.

COLEMAN MEMBER

The Coleman Member of the Gowganda Formation consists of many rock types and lithofacies as summarized in Table 9 and in Figures 15 and 16. A detailed description of the field relations of the rock units is given in the following sections.

Basal Conglomerate – Map Unit 4a

Basal breccias occur above the Archean basement rocks in a few localities. One of these is west of Johnson Lake along Highway 11. Here the breccia consists of a 3 to 5 m thick unit of 10 to 25 cm angular blocks with only minor sand matrix. This unit is interpreted as an *in situ* frost-crack or periglacial breccia.

Near the northeast corner of the map area another basal unit occurs. It is a matrix-supported conglomerate with some 2 to 4 cm subangular granitic clasts set in a coarse sand and granule matrix. That matrix has a composition and appearance similar to altered and decomposed granite. Thus, it is also referred to as granite wash.

Nearby, similar rocks consist of large 1 m size granitic boulders in a granite wash matrix of less than 10%. These granite boulders represent a weathered regolith and are possibly evidence for subaerial exposure. *In situ* spheroidal weathering of granites has resulted in rounded fragments (Photo 3). Overlying this unit at several localities are massive and clast-supported conglomerates (Dcm facies) and debris flows of massive and matrix-supported conglomerates (Dmm facies). A representative analysis of a basal regolithic conglomerate (Sample No. 20) is presented in Table 10.

Clast-supported and Massive Conglomerates (Dcm facies) – Map Unit 4b

Clast-supported and massive conglomerates occur only in a few localities. One of these is along the Montreal River south of Cobalt in the northeastern part of the map area. The conglomerates contain only 25% matrix consisting of poorly sorted, very coarse sand and granules. Composition of clasts is 95% granite and 5% meta-volcanics as rounded, small pebble- to cobble-sized fragments.

Similar rocks occur in the southwest of the map area along the shore of Island Lake. At this locality, matrix and clast-supported conglomerates occur and contain mainly subangular clasts hosted in a poorly sorted sandy matrix. The average size of the 10 largest clasts is 6 cm (cobble size) whereas the largest clasts are 30 cm sized boulders.

Local sedimentary features within a section interbedded with pebbly wacke and arkose include some crude bedding and some reverse grading of debris flow clasts. The interbedded lithologic units probably represent reworked debris flows. This association also illustrates a typical characteristic of the Coleman Member, namely that the rock types generally cannot be traced from one outcrop to the next.

East of Island Lake similar conglomerates contain boulders averaging 40 cm in diameter. They grade laterally and vertically into matrix-supported conglomerates and show no local imbrication.

In the Rib Lake area the clast-supported and massive conglomerate unit has a slightly different clast morphology and smaller pebble-sized clasts hosted in a similar poorly sorted coarse sand matrix.

Matrix-supported and Stratified Conglomerates (Dms facies) – Map Unit 4c

Matrix-supported and stratified conglomerates (Dms facies) occur along Highway 11 in an area west of Johnson Lake. They are mainly reworked and stratified debris flows with 20% clasts. Most contain subrounded pebbles with some minor cobbles and an average large clast size of 3 cm. Composition of clasts indicates granitic > volcanic > jasper. This includes some stream bed conglomerates with channel scours and channel stream fill and no dropstone features (Photo 4). Pebble lags occur at the base of the troughs and channels. All paleocurrent directions are from the east and the north (Figure 18). Generally the sediments are thickly bedded (1 to 5 cm) with poorly defined wispy bedding. In another nearby outcrop the bedding features are similar but it contains larger clasts with an average large clast size of 4 cm (large pebble-sized) with a few boulders 1 m in diameter. Other local sedimentary structures include compaction features caused by some loading of pebbles into the bedding planes. As in all of the Dms conglomerates, the matrix is a poorly sorted wacke with coarse sand-sized grains. The Dms units tend to grade both laterally and vertically in more massive and matrix-supported conglomerates (Dmm) of the predominant debris flow types.

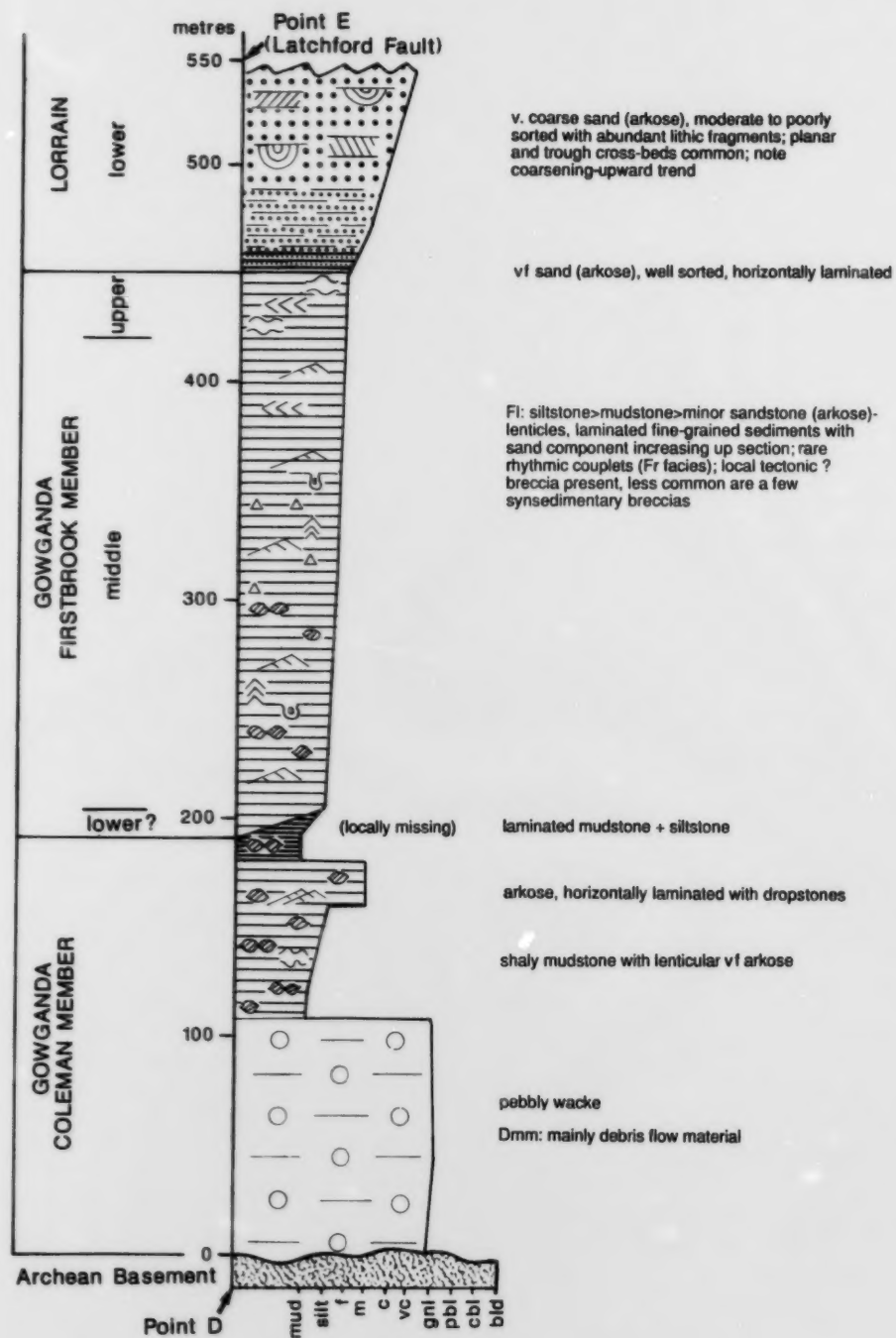


Figure 15. Composite stratigraphic section of Proterozoic sedimentary rocks west of Rib Lake: part of section D-E-F. Legend on facing page.

LEGEND

	current ripples (Sr)		local tectonic breccia
	wave ripples		flat lamination
	herringbone X-laminations		low angle trough scours (Sl)
	separate lenticular laminations (thick, flat)		planar cross-beds (Sp)
	flaser bedding		trough cross-beds (St)
	connected lenticular laminations		massive
	wavy bedding		ball-and-pillow
	type "B" climbing ripples		mudcracks
	muddy intraclasts (Se)		erosional contact
			gradational or conformable contact

SUMMARY OF FACIES CODES

Sand:		Fm:	mudstone
Se:	erosional scours with lag of shaley mudstone intraclasts	Fr:	rhythmically inter-laminated fines
Sh:	horizontal or subhorizontal stratification	Diamictite:	
Sl:	shallow trough scours with low angle cross-bed infill	Dmm:	massive, matrix-supported
Sm:	massive sandstone	Dms:	stratified, matrix-supported
Fines:		Dcm:	massive, clast-supported
Fl:	mudshale with minor sandstone	Dcs:	stratified, clast-supported

ABBREVIATIONS

sd:	sand	f:	fine	wsrt:	well sorted
gnl:	granules	m:	medium	lent:	lenticular
pbis:	pebbles	vc:	very coarse	lmn:	laminations
vf:	very fine	vthk:	very thick	occ:	occasional

Matrix-supported and Massive Conglomerates (Dmm facies) – Map Unit 4d

The most common conglomerates are matrix-supported and massive types (Dmm facies). Some of these are located east of Straight Lake on Roosevelt Road. They contain 15 to 20% fragments hosted in a sandy wacke-like matrix. The average large clast size ranges from 2 cm in some outcrops to 16 cm in others. The clasts generally are of 80% granitic and 20% metavolcanic composition.

The Dmm conglomerates in the southern part of the map area can also occur as units intercalated with other lithofacies types. In one outcrop the debris flow conglomerates overlie fine-grained laminated shaly mudstones. In another nearby outcrop the conglomerates exhibit wispy bedding and are interbedded with a 4 cm thick arenite bed with local trough cross-beds (Photo 5) and clast-supported and stratified conglomerates (Dcs facies). Till balls which are interpreted to represent frozen gravel agglomerations also occur at this locality.

Similar conglomerates of the Dmm type also occur along the Montreal River in the northeast part of the

map area. These rocks have a similar average large clast size of 7 cm but show some distinct reverse bedding of large clasts caused by dispersive pressure. Further south along the river, the clast size of the conglomerates increases to large boulders of 40 cm. Some local trough cross-bedding also occurs at this locality. This suggests that in order to carry the larger bed load boulders the velocity of the currents in these areas must have been greater than elsewhere. A representative analysis of a debris flow material (Dmm facies) conglomerate (Sample No. 16) is presented in Table 10.

Clast-supported and Stratified Conglomerates (Dcs facies) – Map Unit 4e

Clast-supported and stratified conglomerates (Dcs facies) have clast compositions and matrix similar to other conglomerates. The clast shape and size however, are different. Generally clasts consist of rounded pebbles rather than subangular cobbles and pebbles. These rock types are not very common but occur locally within some of the previously mentioned Dcm units along Highway 11 and also in the Pine Lake area in the northeast part of the map area.

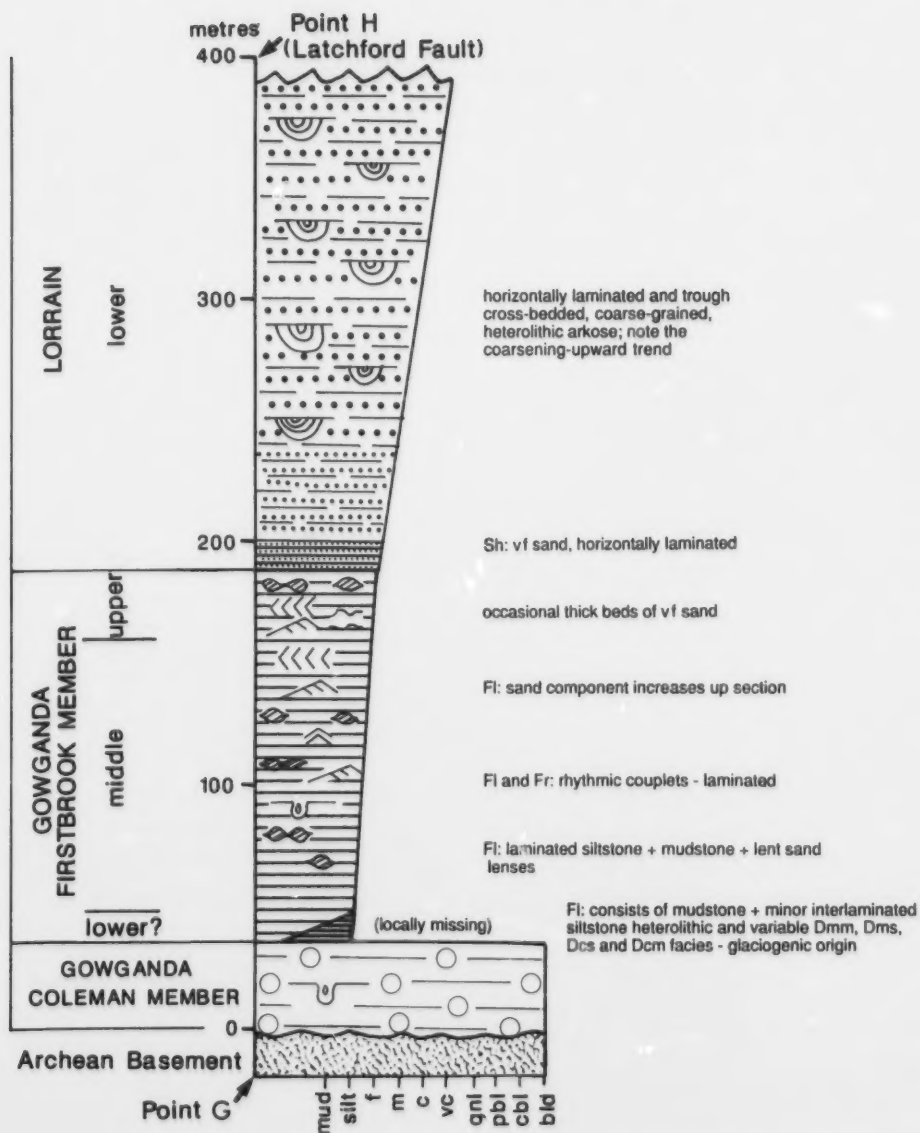


Figure 16. Composite stratigraphic section of Proterozoic sedimentary rocks south of Rib Lake: part of section G-H-I. See Figure 15 for legend.

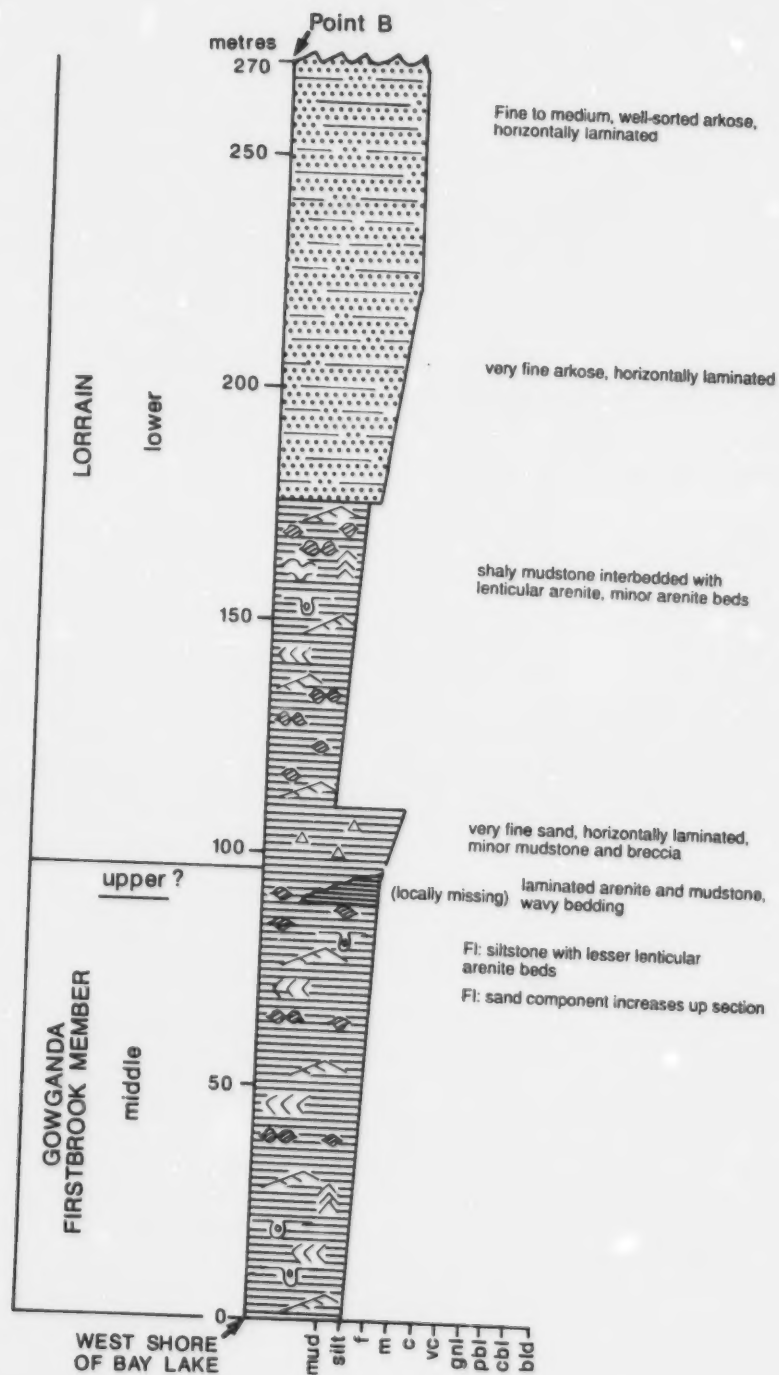


Figure 17. Composite stratigraphic section of Proterozoic sedimentary rocks east of Bay Lake: part of section A-B-C. See Figure 15 for legend.

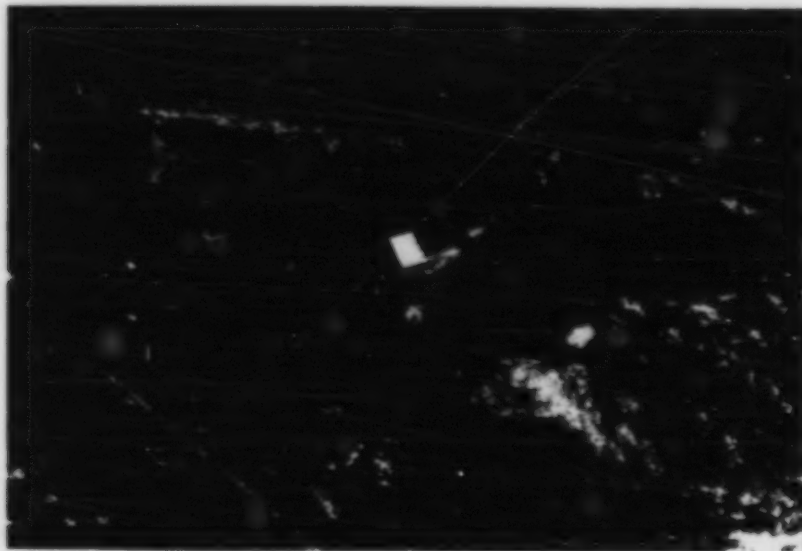


Photo 3. Early Proterozoic Gowganda Formation, Coleman Member basal regolithic conglomerate (map unit 4a). Unit shows extensive sub-aerial weathering and spheroidal weathering of granitic basement to form *in situ* rounded clasts.

Table 8. Terminology of lithofacies for sedimentary rocks of the Gowganda and Lorrain formations.

Abbreviation:

Dcm	Diamictite	clast-supported and massive conglomerates
Des	Diamictite	clast-supported and stratified conglomerates
Dmm	Diamictite	matrix-supported and massive conglomerates
Dms	Diamictite	matrix-supported and stratified conglomerates
Se	Sand	erosional with mud chips
Sf	Sand	fine-grained and micaceous interbeds
Sh	Sand	horizontally laminated
Sl	Sand	low angle planar and trough cross-beds
Sm	Sand	massive
Sp	Sand	planar cross-beds
St	Sand	trough cross-beds
Fl	Fines	laminated
Fm	Fines	massive
Fr	Fines	rhythmic bedded

Classification of facies types according to Miall (1978).

Pebbly Wacke (Dmm facies) – Map Unit 4f

Pebbly wackes of the Dmm lithofacies are one of the main rock types of the Coleman Member within much of the area. These rocks are most common in the south-west part of the map area to the east of Island Lake, west of Rib lake, and south of Anima Nipissing Road. They characteristically contain 10% or less fragments. Clasts are of pebble size; 80% are granitic and 20% volcanic. These rocks are generally poorly sorted, massive and represent less clast-rich equivalents of the Dmm debris flow conglomerates.

Arkoses and Arenites – Map Unit 4g

Arkoses of the Coleman Member occur at several localities. One of these areas is in the northeast section in the vicinity of Borden Lake. Another is south of Anima Nipissing Road. Here they consist of thickly bedded and well-sorted fine sand intercalated with 1 to 3 mm beds of shaly mudstone. The arkose at this location exhibits ripples; “type B” climbing ripples and flaser bedding (Photo 6); normally graded foresets; as well as ball and pillow structures caused by the loading of fine sand in mud.

At another locality on the shores of Portage Bay the arkose is thickly laminated (3 to 10 mm) and consists of fine to very fine sand with lenticular beds of mica-rich and hematitized coarse sand.

At another locality on Island Lake the pebbly arkose is moderate to well sorted with some 1 cm pebbles and with a 15 to 20 cm large cobble dropstone. Other nearby outcrops consist of rippled, very fine sand and also contain pebbles but no dropstones. Similar arkoses south of Anima Nipissing Road are generally mica-rich and also contain some dropstone pebbles. This criteria distinguishes arkoses of the Coleman Member from the younger and nonglaciogenic arkoses of the Lorrain Formation.

In thin section, the arkose consists of a well-sorted framework of subrounded feldspar, quartz and rock fragments with some quartz and feldspar cement. There is little original matrix. Any fine-grained material interstitial to the framework grains represents either epimatrix or pseudomatrix caused by the diagenetic breakdown of feldspar and rock fragments.

A representative analysis of a Coleman Member arkose (Sample No. 19) is given in Table 10.

Table 9. Petrography of the Coleman Member-Gowganda Formation.

Map Unit	4a	4b	4c	4d
Field Name	basal conglomerate	(Dcm facies) conglomerate	(Dms facies) conglomerate	(Dmm facies) conglomerate
Macroscopic Description				
Colour: fresh	light pink-green	light green-grey	light green-grey	light green-grey
weathered	medium pink	light green-grey	light green-grey	light green-grey
Grain size (mm)	matrix: coarse sand or mud	matrix: coarse sand or mud	matrix: coarse sand or mud	matrix: coarse sand
Fragment size(mm) shape	pebbles-boulders 4-3000 subangular	pebbles-boulders 4-3000 subangular	pebbles-boulders 4-3000 subangular	pebbles-cobbles 4-150 subangular
Texture	poorly sorted	poorly sorted	moderately sorted	poorly sorted
Remarks	locally lies above Archean basement; matrix consists of decomposed granitic material	shows clast imbrications; clast supported and massive	stratified and matrix supported; reworked debris flow material	massive and matrix supported; mainly debris flow material
Microscopic Description				
Mode (estimated %)	n = 2	n = 1	n = 0	n = 2
Framework grains: (total 100%)	90	70		90
Quartz fragments		40		40
Feldspar fragments		40		40
Rock fragments		19		40
Granitic fragments	90			20
Opakes (minerals)		1 pyrite		
Matrix: (total includes)	10	30		50
Muscovite		15		5
Chlorite		15		5
Silt + clay fragments				5
other	sand or mud matrix	sand matrix		40
Location of type sample:	0355*	2111		2018
Eastings	602850	601060		593850
Northing	5238050	5236300		5235700
Texture	unaltered granite boulders in a sparse sand matrix	subangular and poorly sorted framework, lithic arkose composition		poorly sorted framework, fine subangular sand grains; matrix composition: lithic arkose wacke
Remarks	only rarely present above Archean basement	clast composition: 80% granitic and 20% volcanic		mainly debris flows with > 15% clasts

Mudstones (Fl facies) - Map Unit 4h

Mudstones are a common rock type in the Coleman Member and may or may not contain dropstones but have thin lenticular sandstone lenses. Disappearance of the thin lenticular sandstone lenses marks the upper limit of the Coleman Member. One locality where the mudstones occur is along Highway 11 east of Island Lake. They occur as claystones containing lenticular sand representing glacial Coleman Member material. The beds are thickly laminated (0.3-1 mm) with erosional bed contacts, some mud rip-up clasts, mud diapirs

(Photo 7), and very regular and continuous parallel laminations. Chloritization is common in the sand lenses. At most localities the sand is generally more chloritized than the mudstones. At another nearby outcrop the mudstones (Fl facies) are interbedded with debris flow conglomerates (Dmm facies). Elsewhere the sand component in the shaly mudstones can exceed 50% and exhibit characteristic wavy bedding and ripples indicating a northerly paleocurrent direction.

Another nearby outcrop has a section with 5 m of mudstones overlying 5 m of Dms conglomerates. The

Table 9. (Continued)

Map Unit	4e	4f	4g	4h
Field Name	(Dcs facies) conglomerate	(Dmm facies) pebbly wacke	(Sh, St facies) arkose	(Fl, Fr facies) mudstone
Macroscopic Description				
Colour: fresh	light green-grey	light green-grey	light buff-grey	light green-grey
weathered	light green-grey	light green-grey	light buff-grey	light green-grey
Grain size (mm)	matrix-coarse sand or mud	matrix-coarse sand	fine sand 0.1-0.2	mudstones < 0.3
Fragment size(mm) shape	pebbles-boulders 4-3000 subangular	pebbles 4-64 subangular	< 5% dropstone pebbles 4-64 subround	< 2% dropstone pebbles 4-64
Texture	poorly sorted	poorly sorted	well sorted	well sorted
Remarks	shows clast imbrications; clast supported and stratified	mainly debris flows with < 10% clasts	well sorted and thinly bedded with dropstones	thickly laminated with lenticular sand and chlorite cement; some normal grading
Microscopic Description				
Mode (estimated %)		n = 1	n = 3	n = 3
Framework grains: (totals 100%)		90	90-100	
Quartz fragments		50	45-60	
Feldspar fragments		30	30-40	
Rock fragments		15	5-14	
Opales (minerals)		5	1	5
Matrix (total includes)		pyrite	pyrite	pyrite
Muscovite		50	10	
Chlorite		10	3	
Biotite		10	3	
Carbonate				
Mud beds		50	4	65-75
Silt beds				30-90
Lenticular sand bed			20	10-20
Others				
Location of type sample:				
Easting		0276*	0352	0049
Northing		596520	603150	592000
		5230050	5236780	5236800
Texture		poorly sorted, dispersed sub-angular framework, fine sand	well sorted, condensed fine sand framework, subangular grains	thinly laminated 1-3 mm with some loading features with some possible detrital mica
Remarks		lithic arkonic wacke, massive no bedding	most common rock type in the Coleman Member	several ripples, lenticular lenses of fine sand occur in the mudstone

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0355.

section here is comprised of 85% mudstone, 10% siltstone and 5% sandstone with local till pellets (Photo 8). Minor tectonic or fluidized breccias occur in this outcrop and appear to be associated with a local kink band.

Elsewhere in the same area mudstones host lenticular to regular planar sand beds which commonly exhibit graded bedding and contain 3% dropstones and granular grit. Strongly chloritized till pellets also occur and consist of 5 mm diameter balls of very coarse sand.

In another local section pebbly wackes overlie an interbedded arenite and mudstone sequence with coarse-grained sand and 1 to 2 mm thick mudstone laminae. Sedimentary features such as normal grading, flaser bedding and climbing ripples occur in some arenite beds. Again, till pellets occur but are generally minor. Along the railway south of Roosevelt Road the mudstone unit contains only 5% sandstone with no dropstones. The beds are normally graded and contain pyrite

Table 10. Chemical analyses of Early Proterozoic sedimentary rocks from the Gowganda and Lorrain formations.

Reference No. Sample No.	16 0009*	17 0041	18 0049	21 0045	22 0006	23 0100
Major Elements (wt%)						
SiO ₂	65.80	55.60	58.30	51.90	65.60	83.20
Al ₂ O ₃	15.60	18.70	19.10	20.20	15.30	9.86
Fe ₂ O ₃	2.20	2.79	3.26	2.00	2.22	0.26
FeO	4.73	6.85	4.79	9.18	5.06	0.67
MgO	2.12	2.60	2.58	2.82	2.88	0.70
CaO	0.51	1.13	0.74	1.35	0.26	0.09
Na ₂ O	4.90	1.64	1.91	1.42	3.37	2.22
K ₂ O	0.80	3.78	4.03	3.54	1.51	1.47
TiO ₂	0.47	0.64	0.62	0.71	0.29	0.07
P ₂ O ₅	0.10	0.27	0.17	0.26	0.04	0.01
MnO	0.05	0.10	0.12	0.14	0.09	0.01
CO ₂	0.08	0.34	0.33	0.68	0.11	0.06
S	0.02	0.01	0.01	0.02	0.01	0.01
H ₂ O ⁺	2.05	3.98	3.82	5.08	2.96	0.52
H ₂ O ⁻	00.00	0.08	0.11	0.20	0.13	0.06
TOTAL	99.40	98.50	99.90	99.50	99.80	99.20
LOI	1.90	3.60	3.30	4.30	2.60	0.60
%	2.71	2.82	2.78	2.83	2.73	2.64
Trace Elements (ppm)						
Ag AA	-2	-2	-2	-2	-2	-2
As AA	1	-1	5.50	80	3	-1
Bi AA	-0.10	0.10	0.20	0.50	0.20	-0.10
Co AA	25	30	27	47	30	-5
Cr AA	149	167	148	175	57	12
Cu AA	16	14	36	150	12	7
Ni AA	54	67	66	83	78	10
Pb AA	-10	-10	-10	-10	-10	-10
Zn AA	42	89	65	91	75	8
Be ICP/OES	2	3	3	3	2	-1
Mo ICP/OES	-10	11	11	12	-10	-10
Sc ICP/OES	14	21	21	22	8	2
Sr ICP/OES	86	61	72	50	96	36
V ICP/OES	68	140	136	154	60	14
Y ICP/OES	12	14	10	13	-5	5
Hg AA (ppb)	5	-5	5	7	6	-5
Au AA	-2	-2	2	-2	2	-2
Pt AA "	2	2	2	4	3	-1
Pd AA "	-1	2	2	3	-1	-1

Abbreviations: AA: Atomic Absorption; ICP: Induced Coupled Plasma; OES: Optical Emission Spectrometry

in very fine chloritized sand. Minor amounts of pyrite commonly occur in mudstones of the Coleman Member. Local sandstone beds have asymmetric (current) ripples whereas starved ripples are more common within lenticular sand lenses.

Mudstones in the Island Lake area are interbedded with 1 to 6 cm thick arkose beds and exhibit some wavy bedding with dropstones (Photo 9), sand rip-up clasts in the sand beds, and some starved ripples.

Elsewhere, in the northeast part of the area, mudstones occur along the Montreal River. In these outcrops loading features such as ball and pillow structures, and wavy bedding are common.

Thin section examination (Table 9) indicates that most of the rocks, with the exception of the arenites and mudstones, are poorly sorted and contain abundant rock fragments. Within mudstones some of the larger musco-

vite grains are interpreted as detrital muscovite. The interlaminated sand lenses are well-sorted but contain variable amounts of chlorite cement. Microscopic sedimentary features such as loading and graded bedding are also common.

Representative analyses of a claystone (Sample No. 17) and a mudstone with rippled and lenticular sand lenses (Sample No. 18) are presented in Table 10.

FIRSTBROOK MEMBER

The Firstbrook Member is subdivided into a lower mudstone, middle siltstone and upper arenite section according to the criteria of Rainbird (1988) and Born and Burbidge (in press). These units are summarized in Table 11 and in Figures 15, 16 and 17. A more detailed description is given below.

Table 10. (Continued)

Reference No. Sample No.	24 0123	25 0187	19 0352	20 0322	26 4119
Major Elements (wt%)					
SiO ₂	78.20	60.60	72.20	71.70	69.40
TiO ₂	0.10	0.67	0.29	0.37	0.40
Al ₂ O ₃	11.70	21.00	14.20	13.70	14.30
Fe ₂ O ₃	1.74	2.80	0.94	0.68	0.93
FeO	0.27	0.73	1.46	1.60	2.99
MnO	00.00	0.01	0.01	0.06	0.04
MgO	0.17	1.23	1.19	0.52	1.35
CaO	0.07	0.04	0.18	1.82	1.43
Na ₂ O	0.79	0.89	4.28	5.81	4.74
K ₂ O	4.31	8.13	2.06	0.55	1.24
P ₂ O ₅	0.01	0.01	0.03	0.06	0.07
CO ₂	0.08	0.15	0.37	1.26	0.57
S	0.01	00.00	0.01	0.09	0.06
H ₂ O ⁺	1.11	3.02	1.65	0.88	1.54
H ₂ O ⁻	0.06	1.36	0.18	0.07	0.06
TOTAL	98.60	99.60	99.10	99.20	99.10
LOI	1.20	2.90	1.80	1.80	1.60
sg	2.61	2.70	2.64	2.63	2.77
METHOD					
	0123	0187	0352	0322	4119
Trace Elements (ppm)					
Ag AA	-2	-2	-2	-2	14
As AA	1	-1	-1	3	1
Bi AA	-0.10	-0.10			
Co AA	-5	14	7	9	6
Cr AA	21	110	52	30	10
Cu AA	9	7	8	18	10
Ni AA	11	21	28	10	7
Pb AA	11	11	-10	-10	-10
Zn AA	5	10	19	22	35
B ICP/OES			17	6	14
Be ICP/OES	1	4	1	-1	1
Co ICP/OES			7	8	6
Cu ICP/OES			6	17	8
Mo ICP/OES	-10	-10	-10	-10	-10
Ni ICP/OES			26	10	8
Sc ICP/OES	4	13	6	7	8
Sr ICP/OES	51	40	55	89	67
V ICP/OES	24	83	45	28	37
Y ICP/OES	-5	-5	-5	17	24
Zn ICP/OES			16	18	28
Hg AA (ppb)	-5	7			
Au AA "	-2	-2	-2	4	-2
Pt AA "	-1	-1			
Pd AA "	-1	-1			

Abbreviations: AA: Atomic Absorption; ICP: Induced Coupled Plasma; OES: Optical Emission Spectrometry

16. matrix-supported conglomerates, debris flows; Coleman Member, Gowganda Formation

17. claystone; Coleman Member, Gowganda Formation

18. mudstone with sand lenses; Coleman Member, Gowganda Formation

19. arenite; Coleman Member, Gowganda Formation

20. matrix-supported conglomerates, regolithic Archean material; Coleman Member, Gowganda Formation

21. shaly mudstone; lower Firstbrook Member, Gowganda Formation

22. fine-grained arkose; lower Lorrain Formation

23. coarse-grained arkose; lower Lorrain Formation

24. coarse-grained arkose; lower Lorrain Formation, near the top of section

25. micaceous fine-grained sand and silt arkose (Sf facies), fine grained capping units; lower Lorrain Formation

26. shaly mudstone (Fl facies); lower Lorrain Formation

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PIB-0009.

Lower Unit: Mudstones — Map Unit 5a

The lower mudstones occur only locally in the map area and represent a minor rock type. The main area of this rock type is along Highway 11 west of Straight Lake and

near Bay Lake. The unit consists of mudstone and 10 to 35% siltstone as thinly laminated (1 to 2 mm) and non-rhythmic sediments which do not contain any drop-stones. The silt commonly occurs as planar beds but also

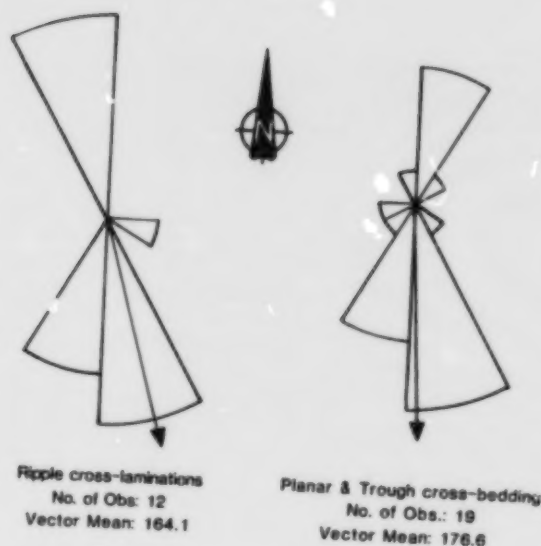


Figure 18. Paleocurrent data for the Early Proterozoic Coleman Member of the Gowganda Formation.

as rare lenticular lenses interlaminated with mudstone. The sediments have a characteristic subconchoidal fracture pattern and a light grey-green colour, not the common maroon colouration of the rest of the sediments of the Firstbrook Member. Local tectonic brecciation and kink bands are common in these sediments.

A representative geochemical analysis of a mudstone (Sample No. 21) is given in Table 10.

Middle Unit: Siltstones — Map Unit 5b

The middle Firstbrook Member consists mainly of siltstones with lesser amounts of mudstones and sandstones. It is the most extensive part of the Firstbrook Member and is fairly widespread in its distribution.

One area where the middle Firstbrook Member occurs is around Bay Lake where the common interbedded rock types are 60% siltstone, 30% mudstone and 10% sandstone. The sandstone commonly occurs as chloritized, lenticular beds with starved ripples, and occasional flaser bedding and climbing ripples. The sand beds are generally green in colour whereas the mud beds are maroon and siltstones are light grey. Rarely, the colouration is reversed with maroon siltstones and grey mudstones. Another characteristic of the middle Firstbrook Member strata is the fairly widespread occurrence of disseminated pyrite. This is probably a good indication of the general reducing environment during which the sediments were deposited.

In the area west of Rib Lake the sediments of the middle unit are thickly laminated and exhibit rare rhythmic bedding, and herringbone cross-laminations (Photo 10). Common rippled sand beds locally exhibit some straight-crested and bifurcating wave ripples and wavy bedding. Some thin turbiditic units with ACE subdivisions (Walker 1984) also occur in this area. Loading features such as ball and pillow structures are common; mud diapirs are more rare. These are caused by the loading of fine sand into the underlying mud or silt beds. Several syndimentary breccias (Photo 11) with slump features occur but are much less abundant than angular tectonic breccias (Photo 12) with associated kink bands (Photo 13).

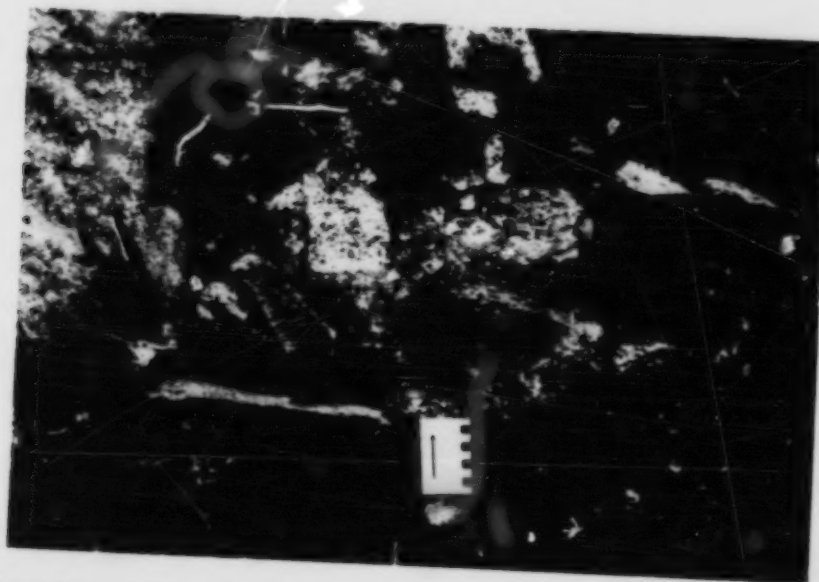


Photo 4. Early Proterozoic Gowganda Formation, Coleman Member: trough cross-beds with pebble lags and channels in matrix-supported and stratified conglomerates (Dms facies).



Photo 5. Early Proterozoic Gowganda Formation, Coleman Member: trough cross-bedded arkose truncating an underlying matrix-supported and massive debris flow conglomerate (Dmm facies).

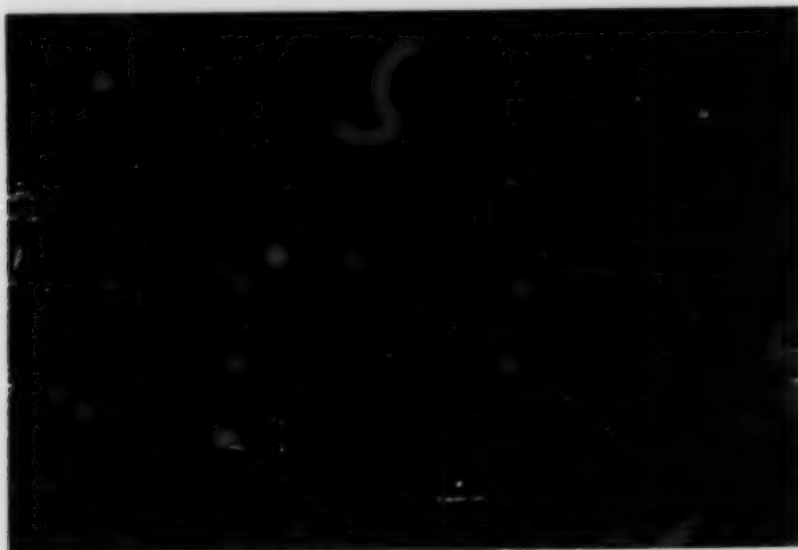


Photo 6. Early Proterozoic Gowganda Formation, Coleman Member: "Type B" climbing ripples and flaser bedding in arkose and interlaminated mudstones.



Photo 7. Early Proterozoic Gowganda Formation, Coleman Member: soft sediment deformation by mud diapirs in mudstones and interlaminated arkose.



Photo 8. Early Proterozoic Gowganda Formation, Coleman Member: local postdepositional breccias in mudstones. Till pellets show chlorite-spotted alteration associated with contact metamorphism by Nipissing diabase sills.



Photo 9. Early Proterozoic Gowganda Formation, Coleman Member: mudstone showing compaction and rucking features within the coarse sand laminae—characteristic of glacial debris and ice-rafted debris.

Upper Unit: Arenites — Map Unit 5c

Sediments of the upper Firstbrook Member are dominated by arenites interbedded with lesser amounts of siltstones and mudstones. The area underlain by these rocks is more widespread than to the west in Brigstocke and Kittson townships (Born and Burbidge, in press). Upper Firstbrook Member strata occur along Roosevelt Road as rippled fine sand (arkose) with 10 to 30% mud laminae (Photo 14). Several wave ripple crests are observed on bedding planes. Graded beds and herringbone cross-laminations and some ABE turbidite couplets (Walker 1984) also occur. Local rhythmic Bouma cycles indicative of turbidites are approximately 20 cm thick and exhibit some wavy bedding. In the Portage Bay area, similar rocks exhibit nonrhythmic bedding, well-developed ripples, ball and pillow loading features, and rare ACE turbidites. Some of the internal laminations are tangential, nonplanar and indicative of possible turbulent flow related to trough cross-bedding rather than simple planar flow.

Along the shore of Rib Lake the upper Firstbrook unit hosts several slump folds indicative of synsedimentary deformation (Photo 11) within very fine-grained and very thinly to thinly bedded (1 to 10 cm) arkose. At Sans Souci Island, convolute bedding and ball and pillow structures characteristic of dewatering and loading features are abundant in the uppermost part of the unit just below the lower Lorrain Formation. Rarely, low angle "Type B" climbing ripples in very fine sand are observed.

In thin section (Table 11), sediments of the Firstbrook Member are generally weakly schistose with chlorite- and muscovite-rich beds. Minor flocculation textures

are rarely observed. Microscopic sedimentary structures such as normal graded bedding, loading features and lenticular beds of sand are common. Chlorite and calcite occur in places as an interstitial cement in the sand lenses. Several larger muscovite grains also occur and suggest a probable detrital rather than diagenetic or metamorphic origin. Rare synsedimentary, soft sediment deformation occurs adjacent to some micro-faults. The adjacent beds indicate bending prior to lithification. More commonly, tectonic brecciation is manifested by displacements and disruptions in bedding along extensional fractures which were infilled later by chlorite.

Lorrain Formation

The base of the Lorrain Formation is placed following the criteria of Johns (1985), Rainbird (1985) and Born and Burbidge (in press) at the base of the lowermost medium- or thickly bedded sandstone (arkose) unit.

LOWER LORRAIN FORMATION

The lower Lorrain Formation underlies a large portion of the map area and consists of three main rock types. A basal unit of fine to very fine arkose is locally overlain by fine laminated (F1 facies) arenites, siltstones and mudstones similar to those found in the middle and upper Firstbrook Member. A coarse-grained arkose overlies the fine-grained basal arkose in all areas except east of Bay Lake where a mudstone overlies the basal unit. Summaries of the main lithologic units are given in Table 12 and in Figures 15, 16 and 17. A more detailed description is given below.

Table 11. Petrography of the Firstbrook Member, Gowganda Formation.

Map Unit	5a	5b	5c
Field Name	mudstone with minor siltstones	siltstone with minor mudstone and arenite	arenite with minor mudstone and siltstones
Macroscopic Description			
Colour: fresh weathered	medium grey medium grey	medium grey-maroon medium grey-maroon	medium grey-maroon medium grey-maroon
Grain size (mm)	predominantly clay	predominantly silt	predominantly sand
Bed thickness laminations (cm)	thinly laminated < 0.3-1.0	thickly laminated 0.3-1.0	thickly laminated 0.3-1.0
Texture	deltaic	commonly rippled	commonly rippled
Remarks	no sand lower Firstbrook	rare herringbone middle Firstbrook	rare herringbone upper Firstbrook
Microscopic Description			
Mode (estimated %)	n = 3	n = 6	n = 2
Mud bed	65	40	20
Silt bed	35	55	30
Sand bed		5	50
Opagues (minerals)	1-5	1-5	1-5
Location of type sample:			
Easting	0045* 591520	0084 590860	2193 597220
Northing	5237740	5244120	5234670
Texture	clastic	minor graded beds	minor graded beds
Remarks	some flocculation	some internal deformation, lags, loading	some internal deformation, lags, loading

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0045

Basal Unit - Map Unit 6a

One area in which the basal, fine-grained arkose occurs is near Roosevelt Road. It consists of well-sorted fine sand with horizontal flat laminations (Sh facies), rare mud chips (Se facies), heavy mineral bands, convolute bedding, and ball and pillow structures. Locally, there is also a hint of some low angle scours and cross-beds in some of the outcrops (Sl facies). Nearby outcrops are similar but also exhibit a few normally graded pebble lags along the base of some arkose beds.

The lower Lorrain Formation, Firstbrook Member contact is exposed in the vicinity of Bay Lake. It consists of a wavy, possibly erosional surface between the underlying siltstones of the Firstbrook Member and the overlying fine-grained arkoses of the Lorrain Formation.

In the Prud'homme Lake area similar arkoses occur, with additional iron-stained and maroon-coloured varieties. This feature is presumably a result of oxidation during diagenesis. Also present are numerous trough cross-beds (Sl facies) with normally graded foresets and 5 cm thick cosets. These cross-beds can be up to

5 m long and 30 cm thick. There are also some low angle trough and planar cross-beds (Sl facies). The local paleocurrent directions appear to be in a bimodal and bipolar direction common to herringbone patterns characteristic of tidal environments (Figure 19). Other nearby outcrops consist of very fine-grained and thickly laminated arkose and intercalated mudstones common in deltaic rock types (Photo 15).

Fine-grained basal arkoses in the Rib Lake area exhibit a variety of sedimentary structures. Well-developed trough cross-beds occur and could represent 5 to 10 m long point bars with 1 to 1.5 m thick cosets and 0.5 to 1 cm normally graded foresets and heavy mineral lags at the base of beds. Low angle scours with normally graded foresets and 0.5 to 1 m wide channels outline erosional surfaces which have associated mud chips. Ripples formed later are superimposed on the foreset crests also occur and indicate a secondary current direction. The base of erosional low angle scours are rarely outlined by minor pebble lags. Elsewhere on Rib Lake fine-grained arkoses are medium to thickly bedded and commonly rippled with some loading features such as

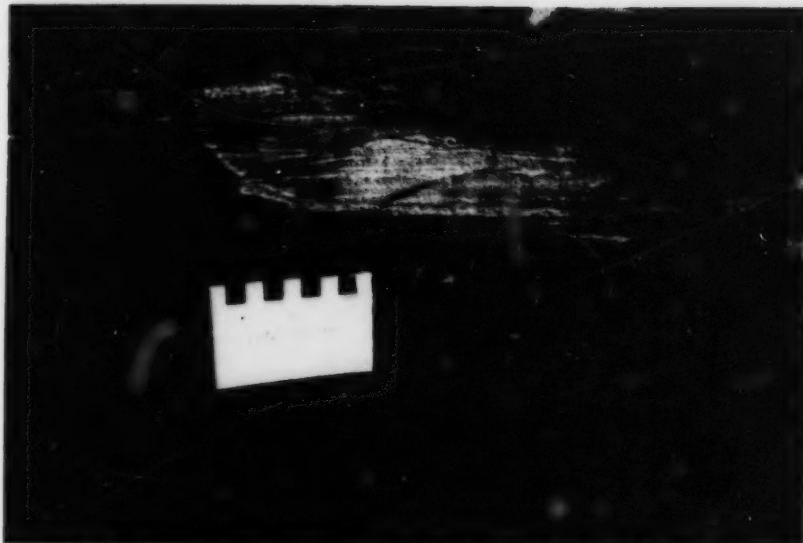


Photo 10. Early Proterozoic Gowganda Formation, Firstbrook Member: siltstone, mudstone of typical middle unit with deltaic features of rippled sand lenticules and rare herringbone cross-laminations. Located along Highway 11, west of Rib Lake in the southern part of the Bay Lake map area.

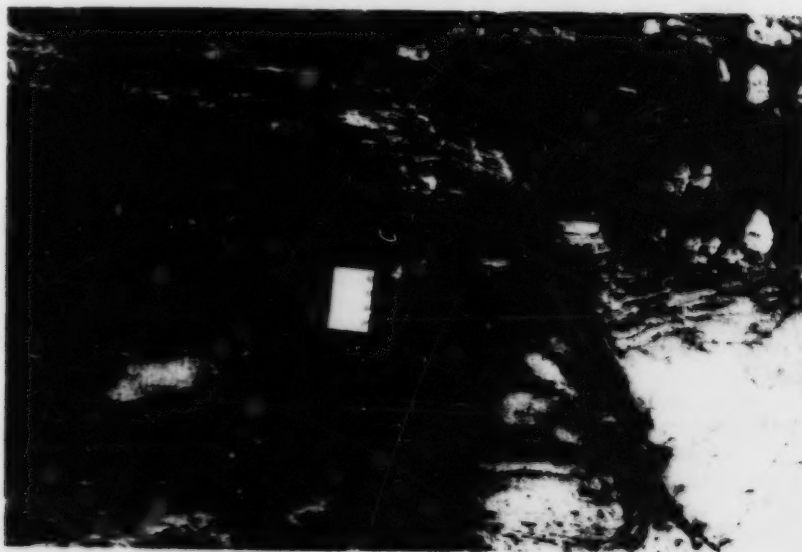


Photo 11. Early Proterozoic Gowganda Formation, Firstbrook Member: upper unit showing synsedimentary deformation and slumping with a normal growth fault. Note the undisturbed upper beds. Located along Highway 11, west of Rib Lake in the southern part of the Bay Lake map area.

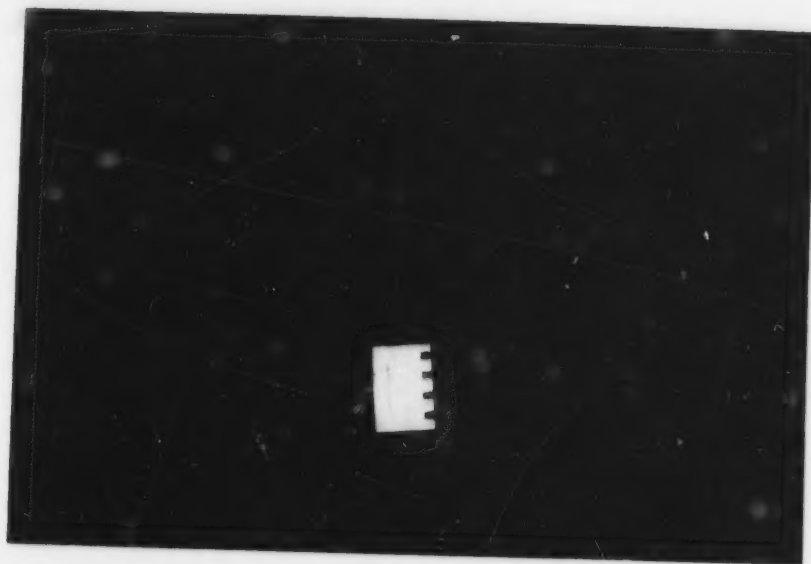


Photo 12. Early Proterozoic Gowganda Formation, Firstbrook Member: middle unit showing tectonic breccia comprised of angular 4 to 6 cm clasts which show little or no internal deformation; generally accompanied by local kink bands. Located along Roosevelt Road north of Hearst Lake in the central part of the Bay Lake map area.

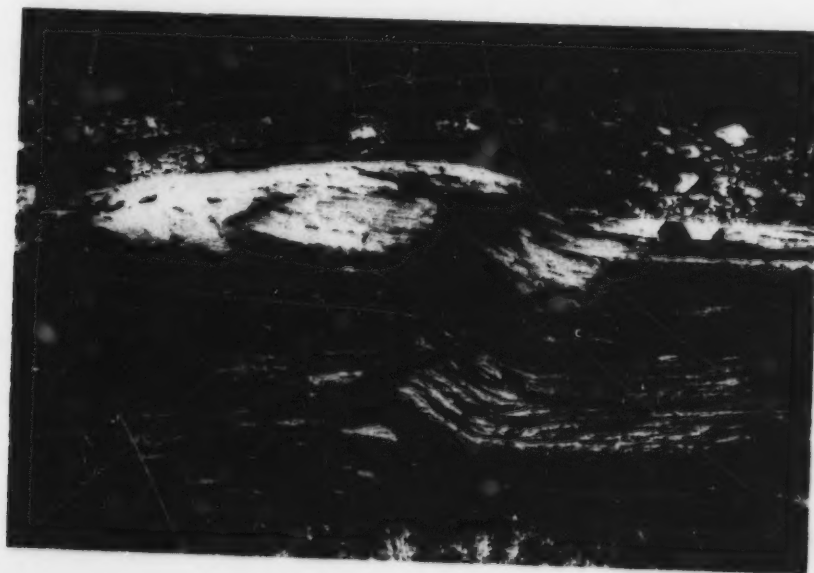


Photo 13. Early Proterozoic Gowganda Formation, Firstbrook Member: middle unit showing compressional kink bands. Located west of Rib Lake in the southern part of the Bay Lake map area.



Photo 14. Early Proterozoic Gowganda Formation, Firstbrook Member: siltstone, mudstone and arenite showing wavy bedding and ripple cross-laminations in lenticular sand beds. Located west of Rib Lake in the southern part of the Bay Lake map area.

ball and pillow structures (Photo 15). Near the micro-wave tower well-developed trough cross-beds occur as a series of stacked 2 cm wide lunate ripple scours. Nearby, similar fine-grained arkoses, however, are massive and could represent thickly bedded, massive facies arkose (Sm facies).

A representative geochemical analysis of a fine-grained arkose (Sample No. 22) is given in Table 10.

Thin section examinations of the basal fine-grained arkose indicates a rounded and condensed framework of very fine to medium sand (0.06-0.25 mm) with minor detrital micas. Most of the feldspar fragments consist of plagioclase rather than alkali feldspar. Diagenetic effects include minor later hematitization of some grains, and the enlargement and rimming of framework grains by cement. The order of paragenesis of the various cements is quartz, followed by chlorite, muscovite and rare carbonate. Alteration of feldspar to muscovite is minor and presumably represents modification during diagenesis.

Mudstone Unit – Map Unit 6b

A section of laminated arenites, siltstones and mudstones locally overlies the basal arkose in an area to the east of Bay Lake. The arkose beds consist of rippled and chloritized very fine sand interbedded with variable amounts of mudstone and siltstone. The proportion of sand is generally greater than 50% but the percentage of mudstone ranges up to a maximum of 60% and siltstone up to 40%. Similar, less extensive, areas of laminated rocks within the Lorrain Formation of the Bay Lake area occur near Roosevelt, Coleman and Wilson lakes. Some local features in these areas include minor soft

sediment loading of rippled, very fine sand into maroon-coloured mudstones. The rippled sand facies (Sr) contain well-developed ripple crests which can have amplitudes of up to 2 cm (Photo 14).

In terms of rock types and sedimentary structures, these rocks are very similar to other Fl facies rocks in the underlying middle and upper Firstbrook Member. In fact they are mainly classified as Lorrain Formation rocks on the basis of structural superposition above thickly bedded, basal arkoses of the lower Lorrain Formation.

Petrographic examinations indicate that fine-grained laminated mudstones (map unit 6b) consist mainly of mud and lesser silt beds. Both chlorite content and grain size differences define the beds. Wispy lenticular bedding, starved ripples, cross-laminations and some graded bedding occur in the coarser silt beds. Some flattened detrital muscovite occurs in some of the mud beds, otherwise both muscovite and chlorite are a later cement in some of the coarser detrital beds. Other microscopic sedimentary features include loading of silt into underlying mud beds to form small ball and pillow structures.

A representative geochemical analysis of a shaly mudstone (Sample No. 26) is given in Table 10.

Upper Unit – Map Unit 6c

The uppermost unit of the local Lorrain Formation stratigraphic section is represented by medium- to very coarse-grained arkose with moderate to poor sorting and numerous lithic fragments.

Coarse-grained arkoses occur north of Latchford and around Bay Lake. The arkoses contain abundant normally graded trough cross-beds (St facies) (Pho-

Table 12. Petrography of the Lower Lorrain Formation.

Map Unit	6a	6b	6c	6d
Field Name	fine-grained arkose	mudstone	coarse-grained arkose	micaceous arkose
Macroscopic Description				
Colour: fresh	light grey-green	grey-maroon	light grey-green	apple green
weathered	light green-grey	grey-maroon	light green-grey	apple green
Grain size	very fine to medium sand	mudstones and arenites	medium to very coarse sand	very fine to fine sand
(mm)	0.06-0.35	< 0.04	0.35-1.00	0.06-0.25
Fragment size(mm)	rare pebbles	minor lenticular sand lenses	rare pebbles	
shape	4 rounded		4 rounded	
Texture	clastic	tidal	clastic	clastic
Remarks	basal unit	overlies basal unit and overlain by same rock type	upper unit some lithic fragments	fine-grained capping units always micaceous
Microscopic Description				
Mode (estimated %)	n = 7	n = 2	n = 6	n = 1
Framework grains:	100		100	100
(totals 100%)				
Quartz fragments	50			
Feldspar fragments	40		55	40
Rock fragments	< 10		30	50
Opauques	3	5	10	< 10
(minerals)	magnetite	magnetite	5 magnetite	
Mud bed		65		
Silt bed		30		
Sand bed				
Also Present:				
Muscovite	30	30	5-30	30
Chlorite	10-15	5	0-10	
Location of type sample:	0135*	2055	0284	4021
Easting	587299	591150	594150	590800
Northing	5246840	5239950	5233180	5244900
Texture	chlorite as cement	chlorite as cement	chlorite as cement	
Remarks	muscovite from feldspar breakdown, epimatrix moderately sorted			detrital mica

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0135

to 16), low angle scours (SI facies) and lesser planar cross-beds (Sp facies; Photo 17). The troughs are characteristically tangential with 15 cm thick cosets and commonly grade from pebble lags at the base to medium sand on the top of the foresets. The largest clasts found in the base lags was an 8 cm cobble which is indicative of strong local currents. Planar cross-beds have cosets up to 1 m thick and 1 to 2 cm thick normally graded foresets (Photo 18). Both types usually occur together with troughs dominant over planar sets. A few nearby outcrops are reddish in colour and exhibit some variable hematite alteration. This is manifest as either discrete hematite spots or as widespread iron staining which results in the distinctive deep pink colour. Most of these features are not primary but probably due to alteration during diagenesis or later modification and oxidation.

At Rib Lake there is also a substantial exposure of the coarse arkose. Local sedimentary features include some coarse gravel lags and trough cross-beds. At one outcrop there is a pronounced erosional reactivation surface between cross-bedded coarse and fine sand. Several other outcrops in the area contain the previously described pink-coloured arkose that formed during diagenesis.

The upper arkose units exhibit similar petrographic characteristics to the basal fine-grained arkose except the framework consists of medium and coarse sand (0.35 to 0.69 mm).

Most of the feldspar fragments consist of plagioclase rather than alkali feldspar. Diagenetic effects include minor hematization of some grains, and the en-

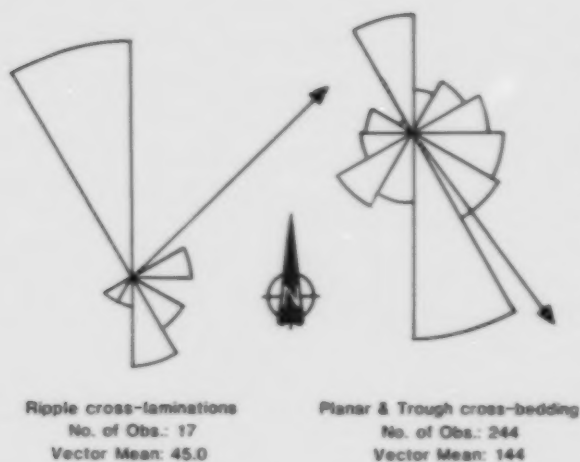


Figure 19. Paleocurrent data for the Early Proterozoic lower Lorrain Formation.

largement and rimming of framework grains by cement. The order of paragenesis of the various cements is quartz, followed by chlorite, muscovite and rare carbonate. Alteration of feldspar to muscovite is minor and presumably represents modification during diagenesis.

Representative geochemical analyses of coarse-grained arkoses (Sample Nos. 23 and 24) are given in Table 10.

Fine-grained, Micaceous Green Arkose – Map Unit 6d

Some fine-grained micaceous interbeds with a characteristic apple green colour mainly occur within the

coarse arkose sequence, however, there are a few examples where they are interbedded with the fine-grained basal arkose.

This type of arkose (map unit 6d) is called Sf facies which refers to a fine-grained sand facies. These arkoses consist of very fine sand in a poorly sorted mica-rich matrix. Micaceous granule interbeds, lags and some normal graded bedding also occur.

These units occur in several localities, one of which is in the vicinity of Bay and Justin lakes. The interbeds are 10 to 40 cm thick with a characteristic sharp upper contact and a more gradational lower contact. The beds can only be traced laterally for 2 to 10 m. Contacts are generally undulatory and can be characterized as pinch and swell features. Internally the beds are commonly horizontally laminated whereas the host rocks are generally trough cross-bedded. This suggests that the fine-grained micaceous beds were probably deposited in a lower energy environment such as a lower flow regime.

Morphology of the beds at Justin Lake is slightly different. In addition to pinch and swell features the 3 cm thick bed also bifurcates and contains some coarse sand. Wispy internal planar cross-laminations are observed with some normal grading from coarse sand at the base to fine sand along the foresets.

Similar rocks occur in the Prud'homme Lake area. The Sf unit is typically 10 cm thick with internal horizontal laminations and a lateral pinch and swell morphology. The lower contact is sharp and possibly erosional whereas the upper contact is more gradational. At this one locality there are 3 fine-grained, micaceous beds intercalated with cross-bedded coarse arkose.

Thin micaceous interbeds also occur in the Rib Lake area with characteristic 8 to 10 cm beds of very fine

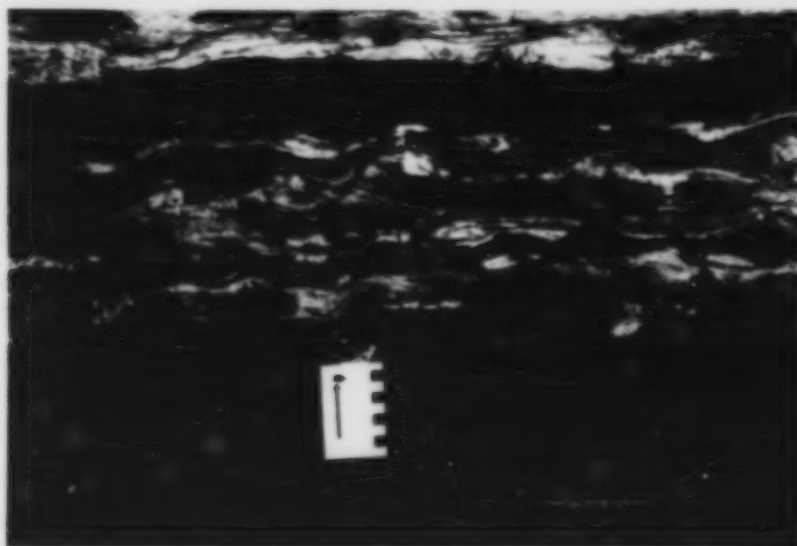


Photo 15. Early Proterozoic Lorrain Formation: lower unit with arenite and mudstone showing wavy bedding and loading features such as ball and pillow structures and convolute bedding. Located along Roosevelt Road north of Hearst Lake in the Bay Lake map area.

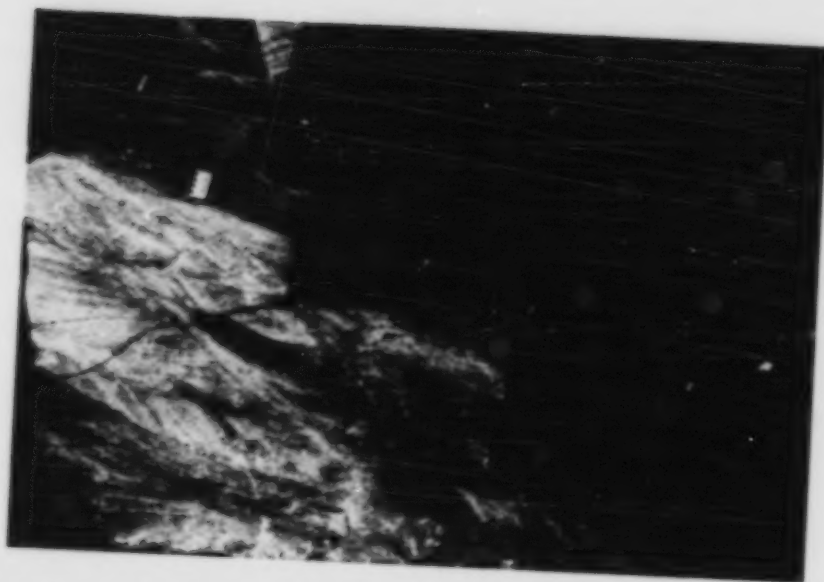


Photo 16. Early Proterozoic Lorrain Formation: upper unit with coarse-grained arkoses showing stacked and well-developed trough cross-bedding. Located along Highway 11, north of Latchford in the northern part of the Bay Lake map area.

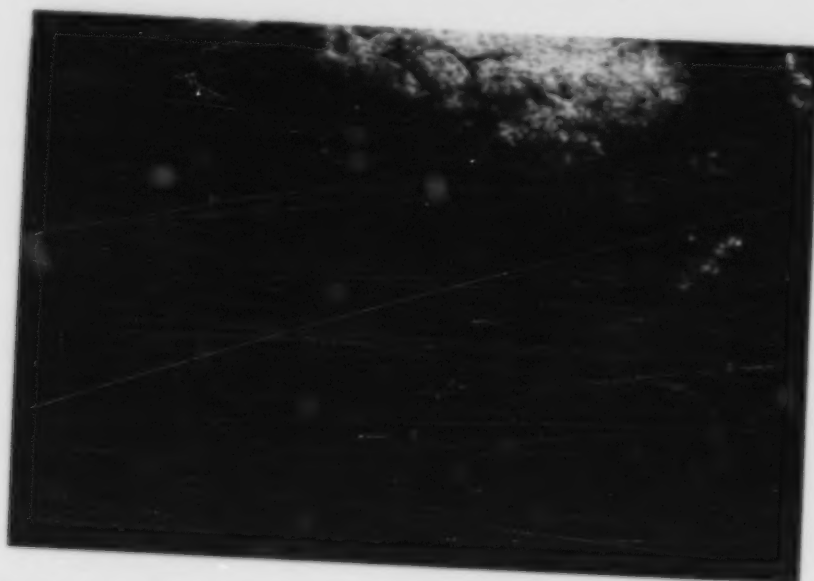


Photo 17. Early Proterozoic Lorrain Formation: upper unit with coarse-grained arkoses exhibiting a probable point bar with 1 to 2 m thick cosets of well-developed planar cross-bedding. Located along Highway 11, north of Latchford, in the northern part of the Bay Lake map area.



Photo 18. Early Proterozoic Lorrain Formation: upper unit with coarse-grained arkoses exhibiting well-developed planar cross-bedding. This is a close-up of the normally graded foresets. Located along Highway 11, north of Latchford, in the northern part of the Bay Lake map area.

sand. Both upper and lower contacts are generally sharp and possibly erosional. Again it appears that an erosional activation surface occurs internally within the mica-rich rock type. Elsewhere in the Rib Lake area similar units exhibit sharp lower and transitional upper contacts. Internally these beds exhibit some possible herringbone planar cross-laminations together with normal graded bedding.

The fine-grained micaceous beds also occur in the Friday Lake area and have typical sharp lower and transitional upper contacts. Within the bed some black, very fine-grained heavy mineral bands occur but are irregular and discontinuous. The interbedded rocks are coarse arkose with abundant quartz and jasper pebbles. The pebbles occur mainly as pebble lags at the base of trough cross-beds. These pebbles show normal upward grading into coarse lithic arkoses.

Petrographic examinations indicate fine-grained micaceous arkoses (map unit 6d) consist of a well- to moderately sorted and condensed framework of sub-rounded fine sand grains (0.22 mm). Muscovite is fairly abundant (30%) and occurs as coarse-grained crystals squeezed between other framework grains. These presumably represent detrital grains, whereas the finer-grained muscovite represents epimatrix which resulted from the diagenetic breakdown of feldspars.

A representative geochemical analysis of a fine-grained micaceous arkose (Sample No. 25) is given in Table 10.

Contact Metamorphic Rocks – Map Unit 6s

Deformation and contact metamorphism of Lorrain Formation arkoses occurs at several localities close to

the Nipissing diabase sills. Metamorphism is usually indicated by circular chlorite spots within the medium to coarse arkose whereas tectonic deformation is indicated by kink bands and associated brecciation.

Minor local deformation associated with contact metamorphism occurs in several areas; namely east of Straight Lake, and near Prud'homme, Rib and Johnson lakes. At the first location along Roosevelt Road fine-grained arkose contains numerous vertically oriented anastomosing kink shears. Spotted chlorite alteration and rare epidote veining occurs in some of the nearby arkoses located close to a large Nipissing diabase body.

Near Johnson Lake thermally altered and chloritized sediments occur. Even the fracture pattern is similar to the adjacent diabase sill.

Sedimentary Depositional Environment of the Gowganda and Lorrain Formations

GOWGANDA FORMATION

Coleman Member

The Coleman Member is widely agreed to be glaciogenic in nature, derived from a northerly retreating continental ice sheet (Schenk 1965; Lindsay 1968; Mustard and Donaldson 1987).

Significant past work includes a study by Mustard and Donaldson (1987) of the Coleman Member in the Cobalt area. Briefly described below are the 4 subdivisions: basal diamictite, fan associations, interfan associations and upper diamictite.

The basal unit includes a basal breccia with Dmm and Dcm conglomerates and is interpreted as a basal till unit on a south-facing passive margin. Deposition occurred in a subaqueous and/or subglacial environment.

The fan association consists of coarsening-upwards mudstone-sandstone, clast-supported conglomerates deposited as prograding subaqueous outwash fans in front of a grounded ice sheet in 50 to 300 m of water.

The interfan area received sediment from meltwater and is characterized mainly by sediment gravity flow units. Included are Dcs sheets or channels with erosive basal contacts. Graded bedding may occur. Sandstone occurs as discontinuous sheets, generally massive or graded and some capped by mudstone. This unit is interpreted as ice-marginal debris flow material with the fine-grained material representing winnowed material distal from the coarse part of the debris flows.

The upper diamictite unit consists mainly of Dmm and Dcm conglomerates, wackes, mudstones and sandstones. Deposition probably occurred mainly as sediment gravity flow.

The vertical distribution of the lithofacies and rock types of the Coleman Member in the Bay Lake area is illustrated in stratigraphic sections shown in Figures 15 and 16. In Figure 16 the Coleman Member consists mainly of coarse sediment debris flow material which corresponds most closely to the upper diamictite association of Mustard and Donaldson (1987).

The stratigraphic section in Figure 15, however, consists of a basal Dmm pebbly wacke overlain by laminar mudstones, overlain by arkoses. Clast-supported conglomerates and both pebbly and nonpebbly shaly mudstones with interlaminated siltstone and very fine sandstone are other common rock types of the Coleman Member. Disappearance of the thin lenticular sandstone beds marks the upper limit of the Coleman Member.

This grouping is similar to the interfan association (Mustard and Donaldson 1987). Deposition occurred as prograding subaqueous outwash fans in front of an ice sheet. Isolated dropstones in the shaly mudstones are interpreted as ice-rafted debris dropped from melting icebergs into mudstones several hundred metres from the ice front. The presence of mudstones indicates a significant depth of marine water at the edge of a continental ice shelf.

Elsewhere the member includes a local basal conglomerate or basement regolith overlain by poorly sorted diamictites containing mud-, sand- and gravel-sized constituents (Mustard 1985; Mustard and Donaldson 1987). Evidence for grounded ice and probable subaerial exposure is rare in the Bay Lake area. More conclusive evidence occurs to the west on Anima Nipissing Lake (Born and Burbidge, in press), in Cobalt (Mustard and Donaldson 1987) and Vogt Township (Schenk 1965). In the Bay Lake area there is little of the clast-poor, monotonous blanketing massive diamictites that correspond to true tillites in

Vogt Township or at Cobalt in the lower diamictite association of Mustard and Donaldson (1987). Rather, both massive and stratified matrix-supported diamictites occur and are believed to represent extensive debris flows. The stratification is probably indicative of reworking prior to the deposition of overlying debris flows. Trough cross-beds are common in many of these rock types (see Figure 18). The paleocurrent data indicates a fairly strong but not a unimodal direction of transport from the north. The debris flows were probably derived from a nearby actively aggrading glacial grounding line and deposited beneath a protective ice shelf. The presence of well-sorted, clast-supported conglomerate is a probable indication of stream flow. The regolith independently indicates subaerial conditions typical of continental ice sheets.

Sedimentary rocks of the Coleman Member are characterized by rapid lateral lithofacies changes and the presence of "dropstones", all indicative of deposition in a glaciomarine environment at the edge of a continental ice shelf (Miall 1985).

Firstbrook Member

The Firstbrook Member is the upper part of the Gowganda Formation and was deposited in a deltaic environment distinctly different from the underlying glaciogenic Coleman Member.

Historically, it has been accepted that the absence of dropstones is one of the markers for the base of the Firstbrook Member throughout the Cobalt area. This is a convenient, although somewhat unreliable criteria. A more accurate criteria is the disappearance of the thin lenticular sandstone beds that mark the upper limit of the Coleman Member. This outlines the upper limit of glacially derived sand material and also the upper extent of deposition under glaciomarine conditions. The basal portion of the Firstbrook Member consists of mudstones and siltstones with no lenticular sand interlaminae.

The only major study of the Firstbrook Member was completed by Rainbird (1985) and Rainbird and Donaldson (1988) and covered most of the Cobalt Basin.

The Firstbrook Member in the Bay Lake area has a maximum thickness of about 260 m and is shown in the 3 stratigraphic sections in Figures 15, 16 and 17. It consists of a single, coarsening-upwards sequence of fine-grained rocks (F1 and F2 lithofacies) which include mud, silt and minor very fine sand (Miall 1978; Rust 1978a, 1978b).

These sediments overlie the Coleman Member and occur as a northwest-trending unit in the western part of Coleman and Gillies Limit townships. The sequence is divisible into a lower, middle and upper unit following the criteria of Rainbird (1985) and Born and Burbidge (1987), although the lowermost unit is thin, poorly exposed, or absent in some parts of the map area. Interlaminated shaly mudstone and siltstone occur in the lower unit, with mudstone representing up to 50% of the rock. Disseminated sulphides are locally present in this unit.

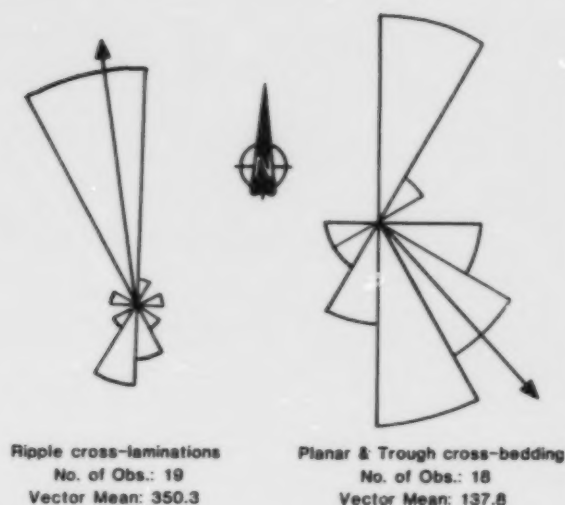


Figure 20. Paleocurrent data for the Early Proterozoic Firstbrook Member of the Gowganda Formation.

In the middle unit, siltstone constitutes over 50% of the rock whereas in the upper unit the proportion of sandstone to siltstone plus shaly mudstone makes up more than 50%. Rare herringbone cross-laminations occur and partly reflect north-northeast and south-southeast bipolar paleocurrent directions for the Firstbrook Member, as illustrated in Figure 20. Measurements of ripple orientations indicate mainly northerly directions whereas the planar and trough cross-beds indicate a more bipolar distribution with the mean vector direction pointing towards the south. This is typical of tidal environments where there is influence from both river-dominated forces and tides and waves that originate within the marine basin.

A deltaic depositional environment was first proposed for the Firstbrook Member by Rainbird (1985). The lower, middle and upper Firstbrook Member represents the prodelta, delta slope and delta foreslope environments, respectively. The lower part of the Lorrain Formation represents the delta topset beds composed of braided fluvial channels and distributaries (Figure 21). Mapping by Born and Burbidge (in press) in Brigstocke and Kittson townships and by the authors in the Bay Lake area confirms this interpretation. The single coarsening-upwards cycle (Rainbird and Donaldson 1988) implies the fluvial input for the Lorrain Formation was a broad fluvial braid plain with coalesced braided deltas. The distributary channels were closely spaced rivermouth bars that produced a sheet-like sand plain. Other sedimentary features such as lenticular, wavy and flaser bedding also suggest a tidal flat environment for the upper part of the Firstbrook Member and the Firstbrook to Lorrain members transition.

Another important depositional characteristic is the appearance of red beds at the base of the middle Firstbrook unit. It implies significant atmospheric changes in which the amount of oxygen was increased dramatically and resulted in the red and hematitized mudstones of the middle Firstbrook unit. Prior to that there had been little oxygen and this is reflected in the general green colour of sediments in the lower Firstbrook Member and in all older strata.

LORRAIN FORMATION

Extensive studies of the Lorrain Formation have been completed by various workers, namely Hadley (1968), Card et al. (1973) and most recently by Rice (1986, 1987, 1988, in press) of the Ontario Geological Survey.

The base of the Lorrain Formation is placed, following the criteria of Johns (1985), Rainbird (1985) and

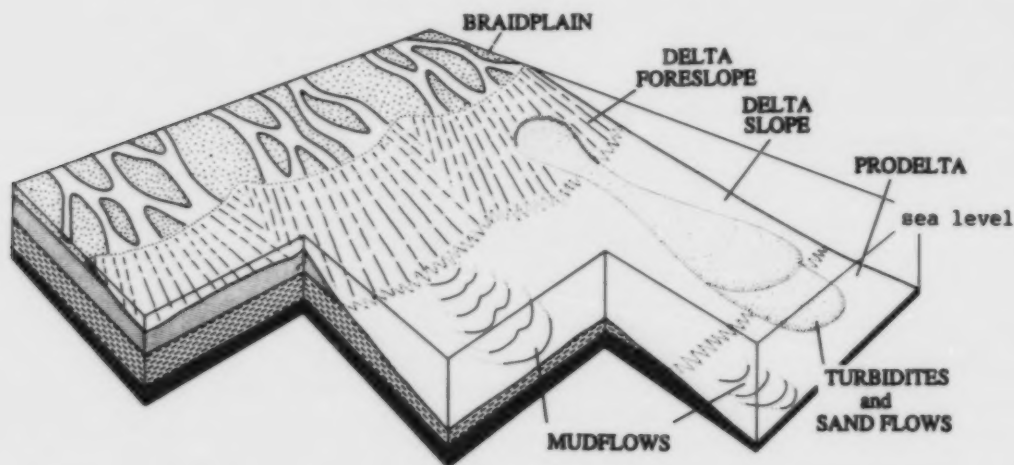


Figure 21. Depositional model for the Firstbrook Member of the Gowganda Formation. Long dimension of block is approximately 5 km; factor of vertical exaggeration is approximately 10. Diagram from Rainbird and Donaldson (1988).

Born and Burbidge (in press) at the base of the lowermost medium or thickly bedded arkose unit.

Rocks of the lower Lorrain Formation locally have a maximum thickness of 250 m and underlie much of the south and northwestern parts of the map area. These sediments are illustrated in 3 stratigraphic columns and indicate thicknesses of only 100 m, 200 m and 160 m for Figures 15, 16 and 17, respectively. All 3 sections show the apparent conformable and transitional nature of the Firstbrook-Lorrain transition.

The lowermost unit consists of a well-sorted, generally horizontally laminated, very fine- and fine-grained, thickly bedded arkose. Characteristic of this unit are local shaly rip-up clasts and some shallow scours. Commonly present are Sh (horizontally laminated sand), Sr (rippled sand) and Sl (low angle trough cross-bedded sand) facies types (Miall 1978). Overlying this are thin local units of laminated shaly mudstone, siltstones and very fine-grained sandstones (Figure 17). These represent Fl (laminated fine-grained mud) and Fr (rhythmically laminated fine-grained mud) lithofacies. Although these are not widespread they are similar to parts of the Lorrain Formation stratigraphic section found to the west in Brigstocke and Kittson townships (Born and Burbidge 1987). The lower Lorrain Formation is also similar in appearance to rocks of the upper and middle Firstbrook Member of the Gowganda Formation and suggests deposition in a similar deltaic environment.

Elsewhere (Figures 15 and 16) the uppermost exposed part of the coarsening-upwards cycles of the Lorrain Formation consists of a moderate- to poorly sorted, medium- to very coarse-grained arkose with common planar and trough cross-beds. These represent St (trough cross-bedded sand) and Sp (planar cross-bedded sand) lithofacies (Miall 1978).

The local paleocurrent data for the lower Lorrain Formation (Figure 19) indicates a bipolar and bimodal distribution with a resultant vector mean to the southeast for the planar and trough cross-beds. Although the source of the currents was in various directions the main directions were from the northwest with a lesser component from the southeast. This type of paleocurrent pattern is most common in deltaic environments or on a shallow marine shelf. The ripple cross-laminations (Figure 19) indicate a more evenly split distribution with strong current influence from the southeast and the northwest. Thus, the resultant vector mean indicates a direction to the northeast which is halfway between the two main current directions. The slightly skewed current patterns suggest that tides and basin currents probably had an important role during deposition of the rippled sand facies near the base of the formation. Also note that the ripple data would come from the basal unit with fine and very fine sand and from any lenticular sand lenses in the mudstone sequences. These mudstone units also probably represent deltaic sediments with strongly bipolar paleocurrent patterns.

Also present locally are some intercalated finer capping units (FCU) as described by Rice (1986, 1987,

1988, in press) and Born (1988). These 5 to 10 cm thick arkose beds are mica rich and consist of fine- to very fine-grained sand with common planar cross-beds.

Sediments of the underlying Firstbrook Member (Gowganda Formation) and the Lorrain Formation represent a southward-prograding and coarsening-upwards marine wedge fed by a braided fluvial system. Upward facies transitions in the lower Lorrain Formation represent sedimentary environments of tidal flat and channel, overlain by topset beds indicating braided stream sediments (Figure 21). Both the coarse-grained nature and immaturity of the sediments supports this type of model. Lithofacies types and rare local erosional contacts between the upper Firstbrook Member and the overlying Lorrain Formation located in Kittson (Born and Burbidge, in press) and Cassels townships (Born 1989) also support a fluvial interpretation. One of the features that Rice (in press) indicates as critical is the diachronous nature of the basal lower Lorrain Formation throughout the basin.

Where the basal member lies directly above the Coleman Member it must be at least partially correlative with the Firstbrook Member of the Gowganda Formation of other regions of the Cobalt Plain. Its grain size generally reflects the grain size of the underlying strata. Thus, the lower Lorrain Formation overlying the coarse-grained sediments of the Coleman Member consists of coarse-grained sand and represents a sand braid plain environment.

Rarely, the Lorrain Formation also directly overlies the Archean basement and consists of some subaerial to subaqueous alluvial fans with coarse conglomerates (Photo 19). In the areas where the Lorrain rock types are underlain by the Firstbrook Member the basal unit is a fine to very fine sand that is time correlative to the middle member of the Lorrain Formation in areas where the Firstbrook Member is absent.

Historically, it has been widely accepted that the Lorrain Formation, due to the immature nature of the coarse-grained sediments, represents a braided fluvial system. It has also been accepted that the Cobalt Basin represents a passive margin setting in which basin subsidence was the main tectonic factor.

It is difficult to envision a fluvial environment within the broader tectonic constraint that evokes a general passive margin and basin subsidence rather than uplift during deposition. It would also be difficult to accumulate up to 2500 m of coarse-grained sediments in a fluvial setting, particularly under a transgressive regime.

Thus, the model proposed by Rice (in press) and favoured by the authors suggests that the transgressions caused the reworking of original topset fluvial beds of the upper Firstbrook Member delta.

Also important in the lower Lorrain Formation rocks are some of the lithofacies arrangements that outline the character of the FCUs. These represent remnants of shelf-type fines that originally were deposited by sediment bypassing the predominant coarser detritus that was part of a shelf-type sand wave complex. Their

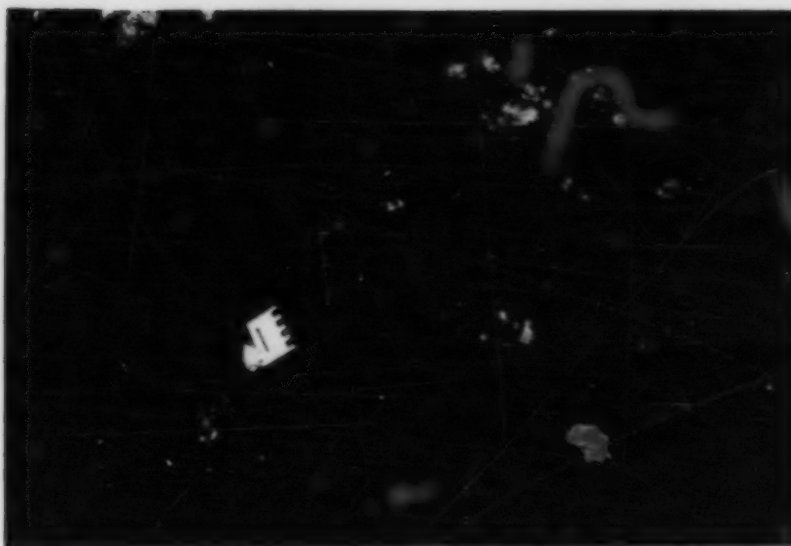


Photo 19. Early Proterozoic Lorrain Formation: basal alluvial fan conglomerate lying directly on the Archean granite basement in Lorrain Township.

sporadic distribution represents only partial preservation below the fair weather wave base. The rest of the continuous sheet-like bodies were presumably removed by episodic storm erosion. Thus, the transgressive basal Lorrain Formation braid plain probably consists of both palimpsest (fluvial deposited, shelf reworked) and moribund (fluvial deposited but not substantially shelf reworked) sediments.

A mechanism to accumulate hundreds of metres of such immature sediment under a transgressive regime has also been proposed by Rice (in press). It requires that numerous episodic stillstands alternated with periods of marine transgression. During the period of non-transgression the fluvial material was allowed to accumulate on a braid plain and then undergo subsequent reworking during the next transgression. This could also explain the occurrence of local deltaic rock types within the lower Lorrain Formation in the area to the east of Bay Lake and near Anima Nipissing Lake. During the stillstands the fluvial delta carrying the material to the braid plain was actually able to prograde out into the marine basin. In this scenario mudstone would be laterally equivalent and overlie basal arkose of the Lorrain Formation. If enough subsidence occurred prior to the subsequent transgression, then some of these deltaic mudstones may be preserved in the stratigraphic record. This mudstone section is shown in Figure 17 and has a thickness of approximately 40 to 60 m. It is both overlain by and overlies fine-grained arkoses of the basal Lorrain Formation typical of the Bay Lake area. The appearance of mudstones above the basal arkose marks the insurging of deltaic material into the subsiding and locally regressive Lorrain Formation marine shelf. The mudstones show all of the typical deltaic characteristics and are lithologically identical to similar Firstbrook sedi-

ments that occur 20 to 30 m lower in the stratigraphic section. Another curious feature of this section is the absence of the upper Firstbrook Member. This is unusual since it commonly underlies the Lorrain Formation in the other two stratigraphic sections and throughout much of the map area. The upper Firstbrook Member is also absent or very thin along Anima Nipissing Lake where there is a thicker section of mudstone in the lower Lorrain Formation.

Deposition environments for mudstone units in the Lorrain Formation and the middle Firstbrook Member were identical except where separated by a period of shelf deposition of very fine sand. The depositional model for the two local coarsening-upwards cycles of siltstones to thickly bedded arenites, and mudstone to thickly bedded arenites can be explained by multiple sedimentary cycles. Such multiple sedimentary cycles in the lower Lorrain Formation were noted by Rainbird (1985) from other areas in the basin. This occurred at the time of deposition of the Firstbrook Member sediments and is related to delta lobe abandonment. In the first step of the model, upper Firstbrook Member sediments were eroded during an extended stillstand by the overlying fluvial topset beds of the lower Lorrain Formation. This was followed by a transgression and switching of the channel mouth to deposit fine-grained distal facies deltaic mud over the former delta foreslope of proximal and fluvial topset sediments. The occurrence of a few local turbidite beds within the mudstone sequence also indicates that minor sediment gravity and turbulent flow occurred during the delta formation.

Extensive studies of the Lorrain Formation have been completed by various workers, namely Hadley (1968), Card et al. (1973), Young (1985) and most recently by Rice (1986, 1987, 1988, in press). The authors fa-

your the tectonic deposition model proposed by Rice (in press). In this model the Lorrain Formation was deposited as a clastic wedge on a passive, Atlantic-type continental margin. It has a southward-subsiding basin with the Cobalt Plain representing an intershell. No record of subsequent uplift or ocean closure is found in the Cobalt Group in general and within the Lorrain Formation in particular. Thus, no tectonic uplift occurred during the deposition of this unit.

Another aspect of the research done by Rice involves the evaluation of paleoplacer gold potential of the Lorrain Formation. If one accepts a depositional environment that included numerous marine transgressions and periodic and intervening stillstands, then the paleoplacer potential of the Lorrain Formation is not very good due to the reworking of braid plain gold concentrations that might have been present originally. In the braid plain environment there is much greater potential to contain economic concentrations of heavy minerals such as gold. Rice (in press) states that it is doubtful that any economic concentrations of gold were preserved and/or can be recognized within the Lorrain Formation in general and particularly in the lower part of the formation. Thus, the potential for gold exploration in the lower Lorrain Formation is probably low.

COMPOSITE DEPOSITIONAL SEQUENCE

The Coleman Member of the Gowganda Formation is a thin, heterolithic, laterally variable sequence of mainly stratified matrix- and clast-supported diamictites and other associated rocks. It represents subaqueous deposition near the grounding line of a continental glacier.

The Firstbrook Member and the Lorrain Formation represent a southward-prograding coarsening-upwards marine clastic wedge fed by a braided fluvial system, possibly South Saskatchewan type (Miall 1978). Upward facies transitions are prodelta through delta slope and foreslope, to tidal flat and channel, overlain by braided fluvial topset beds. The broad fluvial braid plain then underwent numerous marine transgressions and stillstands to produce the resultant lower Lorrain Formation sedimentary package. This package consists of a complex intermixing of palimpsest and moribund sand bodies as part of a marine intershell depositional environment. It also includes the incursion of some local deltaic sediments and the preservation of a mudstone package near the base of the formation.

Mafic Intrusive Rocks

NIPISSING DIABASE

Introduction

Nipissing intrusive rocks constitute a major rock type throughout the Bay Lake map area. They are spatially related to cobalt-copper-silver mineral occurrences in

the nearby Cobalt mining camp as well as in the Bay Lake area.

Early Proterozoic Nipissing diabase forms several east-trending sills (500 m thick maximum) and minor dikes which intrude all of the older rock types. The 3 main sills are located in the Portage Bay area in the north, in the Island Lake to Johnson Lake to Hound Chute area in the central part, and in the Rib Lake to Pine Lake area in the south (Figures 1, 2, 3, 4 and 5). Coarse-grained quartz gabbro and hypersthene gabbro are the main rock types in the lower parts of the sill. Locally, a fine-grained (chilled) gabbro marks the lower contact of the sill. Coarse-grained varied textured gabbro together with subordinate quartz gabbro are characteristic of the upper part of the sills. Granophyre occurs as sporadic lenses or dikes along the upper contact of the sill where it commonly intrudes arkoses of the Lorrain Formation. All of these rock types are summarized in Table 13 and a more detailed description is given in the following section.

Fine-grained Gabbro

Fine-grained and chilled gabbroic rocks define the lower contact of the sills in several areas. At Portage Bay it consists of a mafic, fine-grained phase with greater than 50% amphiboles, 10% quartz and abundant plagioclase with a homogeneous, massive and hypidiomorphic granular texture.

At Prud'homme Lake similar rocks consist of a highly epidotized, very fine-grained to aphanitic gabbro with disseminated pyrite and chalcopyrite. It also exhibits characteristic polygonal joints with apparent weathering and chlorite and epidote alteration along the joint surfaces. Several similar outcrops occur on nearby Hearst and Roosevelt lakes and commonly exhibit associated disseminated sulphides, alteration and/or quartz veining. These rocks are identical to ones described in adjacent Brigstocke Township by Born and Burbidge (in press).

Other similar rocks occur along the eastern shore of Johnson Lake where fine-grained diabase intrudes sediments of the Coleman Member. The result is local epidote alteration of the recrystallized sediments.

Another similar location is along Highway 11 north of Latchford where the contact zone also consists of fine-grained, chloritized and epidotized gabbro. However, the fine-grained rocks occur only 3 to 4 m from some varied textured gabbro. This data indicates that the fine-grained rocks here represent the upper sill contact rather than the lower contact.

In thin section the fine-grained rocks exhibit characteristic relict pilotaxitic textures which are distinct from all other Nipissing rock types.

Hypersthene Gabbro

Hypersthene gabbro is a fairly uncommon rock type and reflects the small amount of unmetamorphosed diabase. Its distinguishing feature is a characteristic brown

Table 13. Petrography of the Early Proterozoic Nipissing diabase.

Map Unit	7a	7c	7e	7f
Field Name	fine-grained gabbro	quartz gabbro	varied textured gabbro	granophyre
Macroscopic Description				
Colour: fresh	light brown-green	light green-grey	light green-grey	light pink-grey
weathered	light green-grey	light green-grey	light green-grey	light pink
Grain size (mm)	very fine grained 0.2-0.3	medium grained 1-2	coarse grained 10-20	medium grained 1-2
Fragment size (mm) shape				
Texture	chilled	subophitic	pegmatitic	granular
Remarks	basal unit locally absent	most common rock type	upper unit	locally along upper contact
Microscopic Description				
Mode (estimated %)	n = 1	n = 9	n = 3	n = 1
Plagioclase		40		45
Actinolite	10	30		
Chlorite				3
Clinopyroxene		10	10	
Hornblende			30	
Biotite		1-5		
Epidote	40		10	
Muscovite	40	1-5	35	5
Quartz	5	5	5	45
Carbonate				2
Myrmekite		5	10	
Opakes (minerals)	2-5 magnetite	1 magnetite	5-10 magnetite	
Location of type sample:				
Easting	2140E*	0036	2020	0056
Northing	600130	600680	594630	592450
	5233440	5233100	5235100	5234730
Texture	pilotaxitic	subophitic	ophitic-subophitic	quartz eyes, volcanic-like
Remarks	retrograde alteration	labradorite (An ₅₅)	some primary amphibole kaersuuite	remelted sediments

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-2140E

spotted alteration on the weathered surface indicative of orthopyroxenes. Other megascopic features such as texture and mineralogy are similar to quartz gabbro. The hypersthene gabbro occurs in many of the same areas as the fine-grained diabase at Portage Bay, Ragged Chute, Prud'homme Lake, Roosevelt Lake, Pine Lake and the area east of Rib Lake.

Quartz Gabbro and Quartz Diabase

Quartz diabase is the main rock type of the Nipissing intrusive rocks. It occurs throughout the sills with minor hypersthene gabbro in the lower part and with varied textured gabbro in the upper part of the sills. Most dikes also consist of quartz gabbro.

The rock is commonly massive and medium to coarse grained with variable amounts of plagioclase, amphibole, quartz and magnetite. Characteristic sub-

ophitic textures are widespread. At many localities, subsequent hydrothermal alteration is associated with numerous local epidote and calcite-quartz veins along shears or joint surfaces. Most of the local mineral showings exhibit varying degrees of hydrothermal alteration along shear and/or joint surfaces. At several localities brecciation and shearing has also resulted in fairly intense chlorite alteration. One of these areas along Highway 11 west of Johnson Lake has a series of *en échelon* thrust faults and shear zones with associated minor pyrite and chalcophyrite and hydrothermal alteration. Also cutting the quartz diabase at this and numerous other locations are late-phase granophyre veins and dikes.

Leucogabbro

A leucocratic variety of quartz gabbro occurs at several localities along Roosevelt Road to the south of Hound

Chute Lake. These rocks have less than 20% feldspar, all of which are amphiboles. The weathered surface is a characteristic pinkish grey with a light grey fresh surface and suggests the presence of some alkali feldspars in addition to plagioclase. Cutting the leucogabbro are several narrow, late-phase granophyre veinlets. These various characteristics suggest that the leucogabbro could be transitional between quartz gabbro and remelted and/or highly fractionated granophyre rocks.

Varied Textured Gabbro

Varied textured gabbro hosted in quartz gabbro is the main rock type throughout the upper part of the sills. Therefore, the exact areal distribution of these diagnostic pegmatite-like rocks outlines and marks the top of each sill.

Throughout the map area this feature indicates that all 3 major sills are gently undulating with both northward and southward dipping limbs. This is a common feature of the Nipissing diabase sills described elsewhere by numerous workers and in nearby areas by Smyk and Owsicki (1986), Conrod (1988) and Born and Burbidge (in press).

The varied textured gabbro occurs as clots of coarse- to very coarse-grained amphibole and plagioclase (5 cm maximum) intergrown in distinct dendritic to subophitic and ophitic textures (Photo 20). It occurs as pods in quartz gabbro forms, or entire outcrops. Occasionally it has been observed as dikes. The scattered nature of the varied textured segregations are probably similar to volatile- and vapour-rich pegmatitic phases during the late stages of granite crystallization.

This varied textured diabase is cut by a more mafic diabase phase at one location along Highway 11 west of Johnson Lake. The contact is unusual in that it is a vertically oriented chilled contact which cuts the subhorizontal diabase sheet. The amount of mafic diabase is extensive, much more than that found in a narrow dike. It is possibly a late Nipissing dike. The other contact is not observed. No other rocks of this type have been discovered in the Bay Lake area.

The presence of some primary, calcium- and titanium-rich amphiboles, namely kaersutite, is an important petrographic feature. It indicates both a significant gaseous and water-rich component during the late-stage crystallization from a calc-alkaline liquid. Minor amounts of alkali feldspar (microcline) occur together with plagioclase in some of the samples. This may also suggest the presence of a late-stage and highly fractionated liquid.

Granophyre

Granophyre is fairly common along the upper contact of the Nipissing diabase sills at several locations. In the area south of Hound Chute Lake there are some extremely altered and partially melted metasediments. It is believed that the granophyre represents melted sediments. An alteration transition occurs from minor chlorite spots in the nearby arkoses to very intense chlorite and alkali feldspar porphyry with Liesegang banding and contorted and folded sediment laminations. Some of the less altered and nearby sediments are also cut by veins and veinlets of the same material. These rocks have a pink granitic composition. The intrusive textures are locally ambiguous. Locally there is a distinct chill zone along the intrusive contact with a corresponding



Photo 20. Early Proterozoic Nipissing diabase: varied textured gabbro characteristic of the upper portions of the sills with coarse pegmatitic patches of feldspars and amphiboles. Located along Highway 11 west of Rib Lake in the southern part of the Bay Lake map area.

grain size increase away from that contact. A corresponding texture in the intruded metasediments also indicates a comparable grain size increase away from the intrusive contact. Other sediment fragments occur as subangular to rounded clasts and suggest the possibility of circular pods that formed by immiscible liquids. At a nearby outcrop the intense alteration is absent but narrow granophyre veinlets cut arkoses of the Lorrain Formation with little apparent local alteration.

Another area of granophyre is along Highway 11 west of Johnson Lake. At this location the granophyre cuts Archean rocks but the nearest known Nipissing diabase rocks are at least several hundred metres to the south. There is, however, a possibility that some diabase rocks could intrude the host Archean rock types at an unknown distance below the granophyre dikes. The granophyre looks like a very fine-grained and glassy rhyolite with quartz phenocrysts. It occurs as a 6 m wide dike with an associated intrusive breccia within the host Archean granitic rocks. This dike cuts the older Archean rocks but is cut by younger Proterozoic olivine diabase dikes of the Sudbury Swarm. Thus, its relative age is probably Early Proterozoic and coincident with the suite of Nipissing intrusive rocks.

A more common type of granophyre dike occurs as 4 to 15 cm wide, vertically oriented veins that cut the upper portions of the Nipissing diabase sills. There are several such dikes and one is in the northeast part of the map area near the Montreal River. The granophyre consist of coarse-grained granite with greater than 15% quartz, 50% amphiboles and 35% alkali feldspars. The fresh and weathered surfaces are a characteristic light pink colour. Textural types range from hypidiomorphic granular to glomeroporphyritic.

At Portage Bay the granophyre is also coarse grained and occurs as several large outcrops and is not just restricted to intrusive dikes. Compositionally, the rocks are granites or quartz monzonites (Streckeisen 1976) with 5% biotite, 10 to 20% quartz, 50% alkali feldspar and lesser plagioclase.

Alteration and Metamorphism of Nipissing Intrusive Rocks

Hydrothermal alteration of Nipissing intrusive rocks occurs along several shear zones, joint surfaces and adjacent to some quartz and carbonate veins that may contain minor sulphides and arsenides. One such occurrence is to the north of Latchford along Highway 11. Others occur at the numerous sulphide showings in the map area. Detailed discussions of the alteration and sulphide occurrences is given in the Economic Geology section under property descriptions. Commonly the hydrothermally altered gabbros contain amphibole, some later biotite, altered plagioclase, epidote, muscovite and minor carbonate. Textures are typically subophitic to blastophitic with amphibole and biotite replacing pyroxenes and epidote and muscovite replacing plagioclase.

In the more typical and "unaltered" rock types the common metamorphic mineral assemblages reflect ei-

ther retrograde deuteric alteration and/or greenschist metamorphic conditions with diagnostic actinolite and epidote as stable mineral assemblages. It is rare for any of the Nipissing rocks to be either unmetamorphosed or exhibit primary pyroxenes and plagioclase. These rare occurrences largely correspond to outcrops of the hypersthene gabbro.

Contact Metamorphic Effects of Nipissing Diabase

Diagnostic chlorite-spotted alteration in adjacent sedimentary rocks is a result of contact metamorphism. Minor associated pyrite mineralization and/or quartz veining is another common feature in many of the contact zones. Such chlorite alteration is most prominent in medium- to coarse-grained arkoses of the Lorrain Formation. Rocks that display this feature occur around Portage Bay and further to the east along Highway 11. In several cases disseminated pyrite occurs at the intrusive diabase contacts. Similar effects occur within the upper Firstbrook Member sand lenses located along Roosevelt Road to the south of Hound Chute Lake.

Chlorite spotting also occurs in coarse sand till pellets within mudstones of the Coleman Member of the Gowganda Formation located to the south of Latchford along Highway 11.

Further to the east along Johnson Lake the intrusive effect of the diabase is more noticeable and is associated with minor pyrite mineralization. At this location the diabase intrudes and incorporates xenoliths of chloritized and recrystallized debris flow material (Dmm) of the Coleman Member. Further to the east, along both Hearst and Roosevelt lakes, brecciation and faulting also occur in close association with the diabase contact and contact metamorphic chlorite spotting. At Roosevelt Lake the breccias and effects of microfaulting exhibit subangular to angular blocks ranging from 1 cm to 1 m in size in arkoses of the lower Lorrain Formation. Nearby outcrops are not tectonized in the same manner but show quartz veins associated with the diabase intrusive contact with laminated arenites of the upper Firstbrook Member.

At Hearst Lake the diabase near the contact is fine grained and epidotized. Similar brecciation and microfaulting has occurred within the adjacent and thermally altered mudstones of the middle Firstbrook Member of the Gowganda Formation. The mudstones host chlorite-spotted lenticular sand lenses. Perpendicular fractures to the contact are represented by closely spaced (1 to 2 cm) joints that were later infilled by chlorite. Some minor sulphide mineralization also occurs along the diabase contact.

Typically the chlorite aggregates occur as coalesced and interconnected spots generally 5 mm in diameter. In other cases a chlorite-rich core is surrounded by a feldspar-rich rim and gives the spots a distinct zoned appearance. Nearby rocks commonly appear to have distinct feldspar clots, also believed to be the product of contact metamorphism.

Table 14. Chemical analyses and normative mineralogy of Early Proterozoic Nipissing diabase rocks and Middle Proterozoic olivine diabase dikes of the Sudbury Swarm.

Reference No.	27	28	29	30	31	32
Sample No.	0016*	0035	0106	2075	0056	0071
Major Elements (wt%)						
SiO ₂	51.30	50.90	73.20	78.20	72.50	45.70
Al ₂ O ₃	15.40	15.10	13.70	12.40	17.50	16.60
Fe ₂ O ₃	2.61	1.70	0.59	0.15	0.41	2.20
FeO	7.65	6.99	2.00	0.67	0.60	12.20
MgO	5.69	10.20	1.07	0.23	0.16	6.25
CaO	9.46	10.70	1.10	0.46	1.05	8.01
Na ₂ O	2.62	1.24	5.14	5.68	4.01	3.87
K ₂ O	0.92	0.45	0.44	0.94	2.81	1.03
TiO ₂	0.80	0.38	0.22	0.19	0.05	2.25
P ₂ O ₅	0.06	0.03	0.06	0.07	0.02	0.84
MnO	0.17	0.18	0.04	0.03	0.02	0.20
CO ₂	0.10	0.08	1.35	0.32	0.39	0.10
S	0.08	0.08	0.02	0.04	0.01	0.08
H ₂ O ⁺	2.70	1.30	0.64	0.50	0.57	0.24
H ₂ O ⁻	0.17	0.19	0.00	0.09	0.00	0.00
TOTAL	99.70	99.50	99.60	99.90	100.10	99.60
LOI	1.80	0.70	1.70	0.60	0.60	0.90
S.G.	2.99	2.99	2.60	2.54	2.64	3.09
METHOD						
	0016	0035	0106	2075	0056	0071
Trace Elements (ppm)						
Ag AA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
As AA	23	N.D.	170	N.D.	1	N.D.
Bi AA	0.10	N.D.	13.70	N.D.	N.D.	N.D.
Co AA	42	46	135	N.D.	N.D.	N.D.
Cr AA	214	176	14	38	N.D.	50
Cu AA	109	143	15	32	N.D.	64
Ni AA	90	178	37	7	19	38
Pb AA	62	N.D.	N.D.	N.D.	N.D.	73
Zn AA	215	74	30	17	12	N.D.
B ICP/OES				5.70	15	143
Be ICP/OES	N.D.	N.D.	N.D.	N.D.	1	2
Co ICP/OES				N.D.		
Cu ICP/OES				N.D.		
Mo ICP/OES	N.D.	N.D.	N.D.	31		11
Ni ICP/OES				N.D.	16	
Sc ICP/OES				8		
Sr ICP/OES	33	35	3	4	2	24
V ICP/OES	196	92	19	67	79	523
Y ICP/OES	239	176	11	23	N.D.	226
Zn ICP/OES	14	7	25	6	15	21
Hg AA (ppb)	44	N.D.	7	15		
Au AA (ppb)	2	8	2		N.D.	N.D.
Pt AA (ppb)	9	6	N.D.	N.D.	N.D.	N.D.
Pd AA (ppb)	13	4	N.D.		N.D.	N.D.

Abbreviations: AA: Atomic Absorption; ICP: Induced Coupled Plasma; OES: Optical Emission Spectrometry; N.D.: not detected

This selective alteration can occur immediately adjacent to the sill or several hundred metres from the contact. Clearly it suggests that the alteration mechanism is strongly influenced by the original and/or selective porosity of the sediments. In thin sections of contact metamorphosed metasediments, granoblastic textures are most common and indicate a degree of recrystallization. This has also resulted in the redistribution of chlorite interstitial to the framework grains into roughly circular chlorite- and muscovite-rich regions within the contact metamorphosed rock.

Petrochemistry of the Nipissing Intrusive Rocks

The results of chemical analyses and normative calculation of 6 representative samples are listed in both Table 4 (Sample No. 5) and Table 14 (Sample Nos. 27 to 31). Of these samples, one (Sample No. 5) represents the fine-grained lower contact zone, two (Sample Nos. 27 and 28) represent samples from the regular quartz diabase sill, and three (Sample Nos. 29 to 31) represent granophyre commonly found along the upper contact of the sill.

Table 14. (Continued)

CIPW Norms						
Reference No. Sample No	27 0016	28 0035	29 0106	30 2075	31 0056	32 0071
APTT	0.1470	0.0726	0.1457	0.1674	0.0000	2.0067
PYRT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ILMN	1.5721	0.7374	0.4283	0.3644	0.0958	4.3099
ORTH	5.6250	2.7170	2.6651	5.6097	16.7542	6.1387
ALBT	22.9384	10.7209	44.5810	48.5382	34.2362	26.1649
ACMT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ANRT	28.4976	35.0533	5.1918	1.8428	5.2558	25.0944
SPHN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUTL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MGNT	3.4504	2.5185	0.8768	0.2196	0.5998	3.2171
HEMT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DIOP	9.4102	11.0805	0.0000	0.0000	0.0000	3.9910
HEDN	6.7471	4.2355	0.0000	0.0000	0.0000	3.8540
WOLL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ENST	10.2999	20.8193	2.7315	0.5785	0.4021	0.0000
FERS	8.4711	9.1286	2.9687	0.8569	0.7241	0.0000
QRTZ	2.8467	2.9204	37.4303	40.4432	35.9261	0.0000
FORS	0.0000	0.0000	0.0000	0.0000	0.0000	9.7048
FAYA	0.0000	0.0000	0.0000	0.0000	0.0000	11.8471
PVSK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NEPH	0.0000	0.0000	0.0000	0.0000	0.0000	3.7177
LEUC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DICA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
KALP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CNDM	0.0000	0.0000	2.9845	1.3833	6.0062	0.0000
CALC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NPLG	55.4040	76.5787	10.4310	3.6577	13.3086	43.6762
FEMG	0.2374	0.3448	0.0497	0.0123	0.0095	0.2882
RMG	0.6151	0.7498	0.5473	0.4701	0.4218	0.5426
RFE	0.3849	0.2502	0.4527	0.5299	0.5782	0.4574
CI	39.9507	48.5198	7.0053	2.0194	1.8218	36.9239

27. Nipissing diabase sill, quartz diabase

28. Nipissing diabase sill, quartz diabase

29. Nipissing diabase, granophyre veins cutting varied textured diabase

30. Nipissing diabase, granophyre dike; rhyolite composition cutting sediments of the Gowganda Formation, Coleman Member

31. Nipissing diabase, granophyre dike; rhyolite composition cutting the Archean basement

32. Olivine diabase dike; Sudbury Swarm, Middle Proterozoic

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0016.

Note: see Table 4 for explanation of CIPW Norm abbreviations.

Sample No. 32 is a younger olivine diabase dike of the Sudbury Swarm. Locations for all samples are given in Figure 6.

These analyses are plotted in Figure 22, a cation plot (Jensen 1976) and Figure 23, the AFM weight percent plot. All of the samples are subalkalic and only the younger olivine diabase (Sample No. 32) and one diabase sample are truly tholeiitic in nature. All the others have a calc-alkalic geochemical affinity. The composition of the fine-grained and chilled diabase (Sample No. 5) most closely resembles that of the original Nipissing liquid. It also indicates that the parent liquid was probably calc-alkaline in nature.

The location of Sample Nos. 27 and 28 in both Figures 22 and 23 indicates quartz diabase is more iron- and magnesium-rich than the chilled sample (Sample No. 5). It also suggests that some crystallization occurred from the bottom upwards with the least fractionated rocks at the base and the most fractionated rocks at the top of the sills. The normative OR-AB-AN feldspar plot (Fig-

ure 24) shows similar results and outlines an increase in fractionation between the chilled samples and the regular quartz diabase. Due to the reconnaissance nature of the geochemical survey, samples of varied textured diabase from the top of the sill were not analyzed. Analyses of similar varied textured diabase from Brigstocke and Kittson townships are, however, reported in Born and Burbidge (in press).

The granophyric rocks (Sample Nos. 29 to 31) are distinctly more alumina-rich (Figure 22) and alkali-rich (Figure 23) than the fine-grained chilled diabase (Sample No. 5). In the normative OR-AB-AN feldspar plot (Figure 24) the granophyre feldspars are more albite-rich and more orthoclase-rich than the postulated original liquid composition represented by Sample No. 5. These data may suggest that a combination of contamination and crystal fractionation produced the granophyric Nipissing rocks.

Chemical characteristics of Nipissing intrusive rocks throughout the Southern Province have been doc-

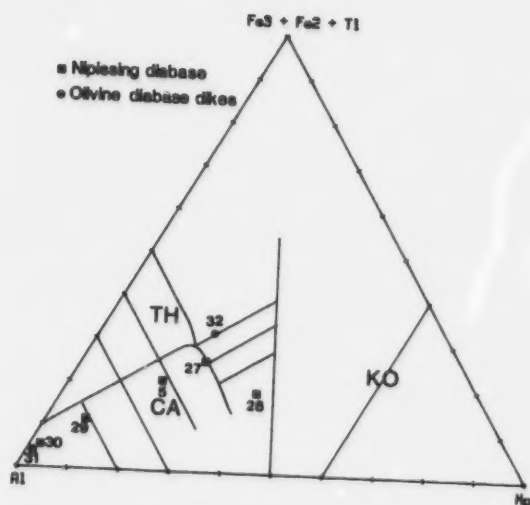


Figure 22. Cation plot for Early Proterozoic Nipissing diabase rocks and Middle Proterozoic olivine diabase dikes. TH-tholeiitic, CA-calc-alkalic, KO-komatiitic (Jensen 1976).

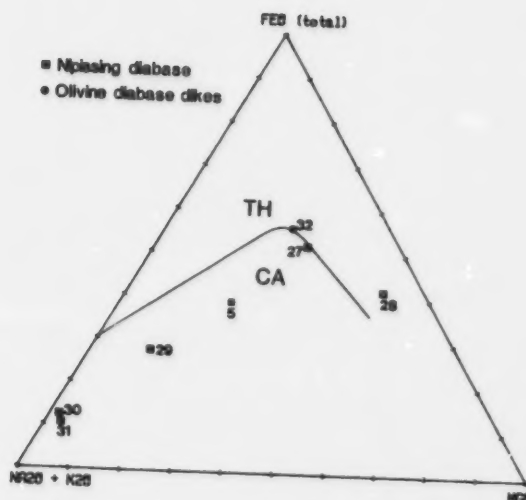


Figure 23. AFM plot for Early Proterozoic Nipissing diabase rocks and Middle Proterozoic olivine diabase dikes. TH-tholeiitic, CA-calc-alkalic (Irvine and Baragar 1971).

umented by several workers and include Card and Pattison (1973), Conrod (1988, 1989), Lightfoot et al. (1986, 1987), and Lightfoot and Naldrett (1987). Much of the work by Conrod (1988) deals with detailed geochemical investigations using isotopes, rare earth element (REE), trace element and platinum group element (PGE) analyses of the Portage Bay sill located in the northeast corner of the Bay Lake map area.

Results from this work indicate that the parental Nipissing magma was remarkably uniform throughout the entire Southern Province. The magma has also undergone considerable trace element enrichment. PGE data and compositional data for olivines suggests the potential for significant PGE mineralization is probably low. Field investigations by Conrod (1988) indicate that the arch zones of the intrusions are regions of intense roof rock melting to produce aplites and granophyres. Thus, the evolution of the Nipissing diabase sills probably included a combination of fractional crystallization and assimilation of the host sedimentary rocks of the Huronian Supergroup. It also suggests that the granophyres were probably produced as a result of direct melting of sediments and without significant chemical interaction with the remainder of the Nipissing magma.

Further work by Conrod (1989) suggests that the Nipissing suite of rocks is not similar to rift-related continental flood basalts such as the Keweenaw basalts. Rather, it is more similar to calc-alkaline collision-type magmas. This is based on a number of trace element discriminant diagrams which indicate that the Nipissing rocks always plot within the calc-alkalic destructive plate margin setting. The chilled Nipissing phases are enriched in the large ion lithophile (LIL) elements; a feature most likely a function of combined fractionation and contamination prior to emplacement. Most similar to the Nipissing suite of rocks are convergent plate vol-

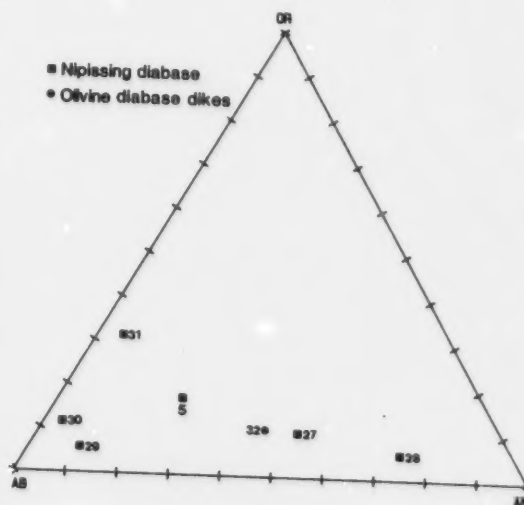


Figure 24. Ternary plot of normative OR-AB-AN for Early Proterozoic Nipissing diabase rocks and Middle Proterozoic olivine diabase.

canics from Chile, however, the chondrite-normalized REE profiles of the Chilean lavas are steeper than those of the Nipissing suite.

A postulated tectonic setting from trace element chemistry may be convenient but it does not take into account all of the other tectonic constraints. It does not explain the relatively undeformed state of the Cobalt Basin if it is part of a converging plate margin. An alternative rift tectonic setting for the Nipissing intrusives has been proposed by Kissin (1988, 1989) and numerous other workers. Part of this evidence is a strong association between the classic five-element (Ni, Co, As, Ag and Bi $\pm$ base metals) suite and rift environments. In the

case of the Nipissing diabase it hosts numerous late-stage calcium veins of this type. The rift environment also fits accepted theories on basin expansion, subsidence and transgression postulated for the Cobalt Plate by most workers. Thus, a rift environment, rather than a converging, destructive plate boundary, would explain more of the associated large-scale geological and tectonic features.

MIDDLE PROTEROZOIC

Mafic Intrusive Rocks

OLIVINE DIABASE DIKES

Two parallel and separate, northwest-trending olivine diabase dikes of the Sudbury Swarm cut across the map area and intrude the sedimentary rocks of the Gowganda and Lorrain formations. A 30 m wide dike is located west of Rib Lake. It consists of porphyritic plagioclase crystals up to 4 cm long set in a coarse-grained and subophitic olivine-, plagioclase- and magnetite-bearing rock (Table 15). Local concentrations of plagioclase range up to 35% of the rock. Characteristic rusty orange-brown weathered and medium grey fresh surfaces are common. Later hematitization occurs and is especially evident along microfractures or joints in the dike. Adjacent sediments of the Firstbrook Member of the Gowganda Formation have been thermally altered and are chlorite-rich near the narrow chilled margin of the dike.

Another dike cuts Coleman Member conglomerates located along the Montreal River in the eastern part of the map area. The dike is 6 m wide and exhibits a characteristic joint pattern parallel to the contact. These similar rocks are coarse grained with an olivine-rich composition and less than 10% plagioclase phenocrysts.

Other narrow (10 cm wide) olivine diabase dikes occur to the east of Island Lake along Highway 11. At this location the fine-grained dikes contain less than 10% plagioclase phenocrysts and intrude the granitic Archean basement rocks.

Throughout most of the Cobalt Plate the dikes are generally traceable over distances of 10 to 30 km. However, the local dike west of Rib Lake can only be traced a distance of 4 km. Card et al. (1973) suggest that the dike swarms occurred as a response to incipient continental rifting caused by convection in the mantle. The most recent age determination for these dikes is 1238 ± 4 Ma (Krogh et al. 1988).

General petrographic characteristics of olivine diabase rock types are summarized in Table 15. A representative chemical analysis and CIPW norm of an olivine diabase (Sample No. 32) is presented in Table 14 along with the data from Early Proterozoic Nipissing diabase rocks.

In terms of classification on the cation plot (Figure 22) the olivine diabase dikes represent high-iron tholeiite liquids. The liquids are relatively iron-rich and moderately fractionated near the middle of the fractionation curve (Figure 23). Normative feldspar compositions (Figure 24) are An_{50} and compare favourably with optically determined values. Feldspar compositions in this range suggest that the olivine diabase dikes crystallized from moderately fractionated basaltic liquids.

LAMPROPHYRE AND DIATREME BRECCIAS

Lamprophyres (Table 15) represent the second type of younger dikes. They are generally medium grained and consist of a biotite-rich matrix rock with 10 to 20% small pebble-sized irregular clasts (Photo 21). These ragged to rounded clasts exhibit characteristic irregular outlines. The dikes are relatively uncommon and form narrow northerly trending dikes 1 to 3 m wide. An absolute age for the dikes is unknown but is probably Middle Proterozoic or younger. In the Bay Lake area the dikes cut only Archean rock types and contain Archean clasts. However, most of the critical field evidence to support a post-Proterozoic age occurs to the west in Brigstocke Township (Born and Burbidge, in press). There, similar dikes cut conglomerates of the Coleman Member of the Early Proterozoic Gowganda Formation. These and other lamprophyre dikes could be related to tectonic events associated with the Timiskaming Rift System (Lovell and Caine 1970).

Lamprophyre dikes have characteristic light green-grey fresh and weathered surfaces and contain abundant biotite, minor epidote and 1 mm spots of carbonate with minor amounts of essential and accidental fragments. The rock type is characteristically unmetamorphosed and nonschistose with no visible internal planar fabric. The rounded nature of most clasts suggests that *in situ* milling may have been an important mechanism during dike emplacement. Accidental clasts consist mainly of granitic and lesser metavolcanic rocks since all dikes of this type in the map area intrude Archean rock types. Amygdules occur in some dike material and may indicate gas escape features.

Petrographic textures are commonly clastic with rounded 1 mm sized volcanic clasts. The interstitial matrix is all biotite and muscovite in a randomly oriented texture. Carbonate alteration is pervasive. General textures and mineral phases would indicate typical retrograde metamorphic conditions accompanied by widespread carbonatization.

Chemical analyses for similar rocks are reported and plotted in Born and Burbidge (in press). These data indicate the lamprophyres are typically magnesium-rich ultramafic rocks with low values of less than 51% SiO_2 .

LAKE TEMAGAMI BRECCIAS

Diatreme breccias (Table 15) within the map area occur to the north of Latchford and are believed by the authors to be related to lamprophyre dikes. They are un-

Table 18. Petrography of Middle Proterozoic olivine diabase dikes, lamprophyre dikes and diatreme breccias.

Map Unit	8b	9a	9b
Field Name	olivine diabase	lamprophyre	Lake Temagami breccia
Macroscopic Description			
Colour: fresh	medium grey	medium green	light green-buff
weathered	medium brown-grey	medium green	light green-buff
Grain size (mm)	medium grained 1-3	medium grained 1-3	medium and fine sand 0.2
Fragment size (mm) shape		accidental granitic 10-20 rounded	subangular arkose fragments 10-20 subrounded
Texture	subophitic	biotite-rich	chlorite-rich
Remarks	plagioclase phenocrysts 10-30%	sharp to transitional dike contacts	diatreme breccia
Microscopic Description Mode (estimated %)	n = 2	n = 1	n = 1
Plagioclase	60		
Actinolite	2		
Tremolite			
Chlorite			30
Olivine	15		20
Orthopyroxene	10		
Biotite	2	25	
Muscovite	5	30	
Quartz		5	
Carbonate		5	
Titanite			
Opyrum (minerals)	5 magnetite		5
Location of type sample:			
Eastings	0071* 593330	0308A 592050	4024 590380
Northings	5233760	5235780	5244940
Texture	subophitic	lepidoblastic	anastomosing veins filled with chlorite
Remarks	labradorite (An ₅₀)	rounded fragments with an unaltered micaceous matrix	subrounded fragments and poorly sorted

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 83PFB-0071.

common and consist of subrounded and essential clasts of arkose 2 to 4 cm in size hosted in a fine-grained sandy matrix (Photo 22). This breccia body appears to be vertical and occurs as irregular-shaped isolated patches, 10 to 30 cm in diameter. Elsewhere, to the west in Brigstocke and Kittson townships (Born and Burbidge, in press) these breccias are more common. In the Temagami and Maple Mountain area similar breccias contain Nipissing diabase fragments and indicate a minimum Middle Proterozoic age.

Both the general morphology and isolated areal distribution of the breccia bodies in all areas tend to rule out a primary sedimentary origin. They, however, may

represent gas escape diatreme breccias and may be related to lamprophyre dikes. Both dikes and diatremes commonly occur along north- and northeast-trending structural lineaments. This type of diatreme breccia is referred to by Born and Burbidge (in press) and the authors as Lake Temagami-type breccias.

In thin section the breccias consist of subangular arkose fragments in a well-sorted and rounded framework of fine-grained quartz and feldspar grains. The arkose is cut by 1 mm wide anastomosing-type veins consisting of 50% chlorite and brecciated, poorly sorted, sedimentary fragments. These fragments are of the same composition as adjacent arkoses of the Lorrain Formation.

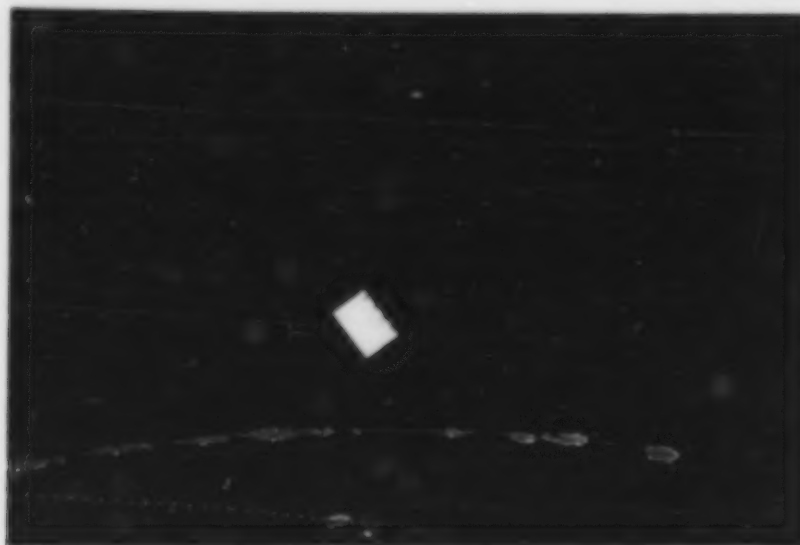


Photo 21. Middle Proterozoic lamprophyre dikes cutting Archean granitic rocks and containing 5 to 10% accidental clasts in a biotite- and muscovite-rich matrix. Located along Highway 11 east of Island Lake in the southern part of the Bay Lake map area.

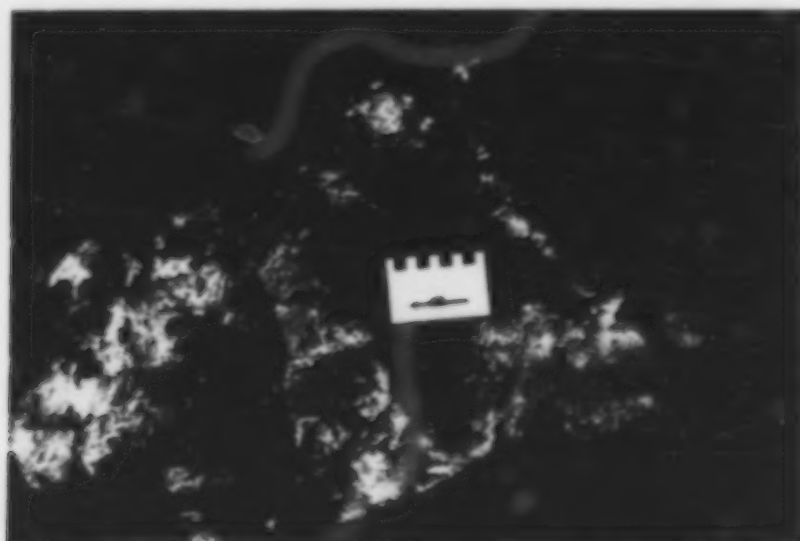


Photo 22. Middle Proterozoic Lake Itimagan-type breccia: possible diatreme breccias hosted in arkoses of the lower Lacmin Formation to the north of Latchford in the northern part of the Bay Lake map area.

PHANEROZOIC

Cenozoic

QUATERNARY

Pleistocene and Recent

Eighty to ninety percent of the map area is covered by overburden which mainly consists of glacial and reworked glacial material. Glacial features such as striae, chattermarks and crescentic fractures commonly indicate a southerly direction of movement. There is also a subsequent but less pervasive 200° glacial direction indicated by some minor striae.

West of Rib Lake in the southwest part of the map area the glacial deposits consist of an area of ground moraine composed of stony till (Roed 1979). Ground moraine consists mainly of sandy bouldery till, usually 3 to 5 m in thickness, and has local relief of 2 to 4 m. This area is generally well drained where there is abundant outcrop but may contain local wet depressions.

Hummocky moraine underlies a large area to the north of Bay Lake. It consists of a stony till composed of sand with boulders as much as 50 m in thickness, but relief is commonly in the order of 10 to 20 m. The area is characterized by outcrop knobs, and kettle and kame

lakes and irregular groupings of hills. Depressions in this unit commonly contain organic material such as wet peat bogs and swamps.

Glaciofluvial outwash deposits occur as an extensive plain or terrace adjacent to the Montreal River and in scattered localities throughout the map area such as adjacent to Johnson, Rib and Bay lakes. These are generally dry, well-drained areas mainly of reworked sand and gravel of a glacial origin.

Recent deposits consist mainly of organic swamp deposits and lake sediments. Such swamps consist mainly of peat which are located along seepage paths or poorly developed streams and local depressions. Swamps such as these are most common in the area directly to the east of Portage Bay in the northwest part of the map area.

Understanding the local glacial geology can be a tool in soil geochemistry surveys for gold and base metal exploration. Sampling of the basal till for mineral exploration and tracing of mineralized float is most easily and efficiently accomplished in areas of ground moraine. Geochemical anomalies in associated organic and alluvial landforms within the ground moraine unit may be of local origin, and follow-up exploration should be easier than in other glacial landforms, such as hummocky moraine. Local depressions in the ground moraine unit may also contain organic material.

Structural and Metamorphic Geology

INTRODUCTION

Archean metavolcanics are the oldest rocks in the area. Deformation, regional metamorphism and emplacement of granitic plutons occurred during the Kenoran Orogeny 2500 Ma or more (Stockwell et al. 1970). Emplacement of the granitic plutons also caused the development of volcanic roof pendants and local migmatite structures along the edges of the granitic body. Local evidence for these processes is seen in Brigstocke Township to the west (Born and Burbidge, in press) but also has been observed in the southwest part of the map area as part of a lithologically complex granitic intrusive and migmatitic terrain.

Extensive block faulting of Archean rocks occurred during extensional tectonics caused by some thermal crustal hot spots or anomalies. This resulted in the development of a series of horst and graben crustal blocks, creating an active rift environment during Early Proterozoic time. Subsequent deposition of Huronian rocks occurred in a series of cratonic sedimentary basins similar to an Atlantic-type passive tectonic margin. Nipissing intrusive rocks were emplaced some 2219 Ma. This was followed by deformation and metamorphism related to the Penokean Orogeny some 1900 Ma (Van Schmus 1965). Further extensional tectonics resulted in the emplacement of Sudbury Swarm dikes some 1240 Ma (Krogh et al. 1988). Lamprophyre and some diatremes occur which are possibly younger than the olivine diabase dikes of the Sudbury Swarm. They may be related to the formation of the Timiskaming Rift System and could be as young as post-Ordovician (Lovell and Caine 1970).

STRUCTURE

Archean plutonic and metavolcanic rocks in the southwestern part of the map area are generally weakly foliated with a near vertical east- and southeast-trending fabric. Archean metavolcanic rocks in the northeast corner have a similar southeast-trending foliation. Orientation of the foliation fabric is generally near vertical but ranges from 70° to the north through vertical to 80° to the south. Younging directions from pillow packing in mafic metavolcanics indicate consistent top directions to the southwest. Local folding appears to be minor. At one location the pillows indicated this southwest younging direction but were slightly overturned by a steep, 80° north-dipping foliation. The volcanic sequence thus appears to be a steeply dipping monoclinical sequence facing to the southwest. Poorly developed jointing occurs within the metavolcanic sequence with east- and southwest-trending joint sets most common. Brittle deformation occurs within a southeast-trending shear zone that cuts Archean metavolcanic rocks east of Island Lake. Minor, associated disseminated pyritic mineralization occurs at several places along this zone. Parallel and

steeply dipping joints commonly occur within Archean rock types throughout this area.

The Latchford Fault is probably related to the Timiskaming Rift Valley (Lovell and Caine 1970). It is a prominent northwest-trending fault that cuts across the central part of the map area. The Montreal River Fault is similar and one of several additional northwest-trending faults and/or lineaments which are prominent throughout the map area. Displacements along these faults appear to be minor, and the local Huronian stratigraphic sequence is essentially intact with no apparent major horizontal or vertical displacements.

Sedimentary rocks of the Gowganda and Lorrain Formations are undeformed in most places. They have locally undergone some gentle flexure folding during the Penokean Orogeny along several gently plunging (10°), subhorizontal, west- and east-trending fold axes. Only a few synclinal and anticlinal folds of this type were observed. Schistosity is only rarely developed in the sediments and its orientation ranges from vertical to 45° to the south. Otherwise, changes in the strike and dip of the strata outline several north-trending gentle fold axes. These are marked on the map face and in the 3 geological cross sections (Figures 3, 4 and 5).

Faulting and subsequent tilting may represent other mechanisms that caused changes in the strike and dip of the strata.

Jointing in the Huronian strata is generally poorly developed. Subvertical- to vertical-dipping joints commonly trend in northwest and northeast directions and suggest the main compression was oriented in a north-south direction.

Several northeast- and northwest-trending shear and extensional fracture zones cut the Proterozoic Nipissing diabase. Some of these have quartz and/or carbonate veins with related minor copper, cobalt and silver mineralizations. A more detailed description of these occurrences is given later in the Economic Geology section. Elsewhere, some prominent extensional fractures do occur but contain only a late infilling of chlorite and no mineralization.

Joint sets are well developed in Nipissing diabase. Vertical-oriented and northwest and northeast joint sets are most common. A less prominent subhorizontal set generally dips 5° to 10° in both the northeast and northwest directions with a similar trend to the vertical joint sets.

Locally extensive, postdepositional breccias occur mainly with rocks of the Gowganda Formation. The majority of the breccias are confined to vertical to subhorizontal zones composed of angular 3 mm to 4 cm sized sedimentary clasts and 3 m blocks which show little or no internal deformation (Photo 12). These types of breccia occur almost exclusively in laminated mudstones of the Firstbrook Member but rarely in mudstones of the Coleman Member and more rarely in arkoses of the

Lorrain Formation. Numerous local compressional kink bands (Photo 13) occur in the adjacent host rocks of the breccias and are usually oriented in a southeasterly direction, commonly parallel to local fold axes and the main direction of northwest faulting. No extensional kink bands were observed. Similar breccia in Brigstocke and Kittson townships have been described by Born and Burbidge (in press). Field evidence in both areas suggested that the breccias were probably not caused by sedimentary slump failure but are related to the intrusion of Nipissing diabase sheets or possible local faulting. In the first scenario, steam or water escape processes, or both, were probable causes of the brecciation.

This can be more easily accepted in areas where these breccias occur in close proximity to Nipissing diabase rocks. Other areas, however, do not have this close lithologic association. Alternatively, regional flexing and faulting of strata parallel to the main Latchford Fault may have caused the main northwest-striking kink folds, associated local schistosity and presumably the brecciation.

Another type of uncommon breccia is the Lake Temagami-type breccia (map unit 9b) discussed in an earlier section. They may represent diatremes and consist of subrounded and essential 2 to 4 cm sized clasts of arkose in a fine-grained sand matrix (Photo 22) and are found at two localities within rocks of the Lorrain Formation. The breccias may represent gas escape features and/or may be related to lamprophyre dikes that commonly occur parallel to north- and northeast-trending structural lineaments.

METAMORPHISM

The grade of regional metamorphism in the area ranges from subgreenschist facies in the Huronian sedimentary rocks to greenschist facies (Winkler 1976) in the Archean metavolcanic rocks. A higher grade of metamorphism that probably corresponds to amphibolite grade contact metamorphism is indicated by partial melting with Archean migmatitic and metaplutonic rocks.

Archean mafic metavolcanic rocks consist of typical greenschist facies mineral assemblages of epidote + albite + actinolite + chlorite + muscovite + calcite + hornblende $\pm$ serpentine + prehnite. With the exception of the last two, all of the above are typical products of lower greenschist or deuteritic or retrograde metamorphism. The presence of hornblende in some coarse-grained amphibolites probably represents some primary hornblende in some synvolcanic rocks or hornblende that crystallized from partially crystallized and recrystallized volcanic material. Field relationships that support this type of interpretation show veinlets and swarms in

the supracrustal rocks adjacent to intrusive granitoid plutons. The coarse-grained amphibolites grade into various lithologic facies of felsic plutonic rocks and suggest significant assimilation probably contemporaneous with granite emplacement during the Kenoran Orogeny (2500 Ma). Similar rock types and textures have been described by Born and Burbidge (in press) in nearby Brigstocke and Kittson townships and by Smyk and Owsiacki (1986) in Banting and Best townships.

The komatiitic suite of mafic volcanics is represented by two petrographic samples. Common retrograde mineral assemblages with serpentine and an extensive carbonatization occur in these samples. No skeletal olivines were observed which indicates the synvolcanic nature of the ultramafic intrusive rocks. The komatiitic basalt suite contains alteration products of epidote and actinolite with extensive carbonate typical of the lower greenschist rocks of the intercalated calc-alkalic andesites. Hornblende in the andesite suite of calc-alkalic rocks is a primary mineral and its presence is not an indication of metamorphic conditions. However, the occurrence of prehnite in some amygdules indicates very low grade metamorphism typical of subgreenschist facies.

Mineral assemblages in the intermediate to felsic plutonic rocks are fairly typical of minor retrograde (deuteritic) alteration of primary hypidiomorphic granular textures. Minor epidote, muscovite, chlorite and carbonate are all alteration products.

Contact metamorphism of sedimentary rocks of the Early Proterozoic Gowganda and Lorrain Formations occurred during the emplacement of Nipissing diabase some 2219 Ma. Extensive chlorite-spotted alteration and feldspar clotting developed mainly within arkoses of the Lorrain Formation near the sill contact.

Mineral assemblages in Nipissing diabase rocks generally reflect greenschist metamorphism with characteristic actinolite + epidote + muscovite as stable alteration products. A few sporadic outcrops of hypersthene gabbro represent rare unmetamorphosed sections of gabbroic rocks. Any metamorphism of the rocks probably occurred during the Penokean Orogeny some 1900 Ma. Minor postintrusive, hydrothermal alteration of Nipissing diabase occurred locally adjacent to joints, shear zones and calcite-rich veins. These veins may also contain minor copper, cobalt and silver mineralization (see "Economic Geology"). Carbonate intergrown with chlorite, biotite and rare actinolite are the typical mineral assemblages of the veins.

Alteration in the olivine diabase and lamprophyre dikes is minor or absent. These Middle Proterozoic rocks have essentially unaltered, primary mineral assemblages.

Correlation of Aeromagnetic and Gravity Data with Geology

The Bay Lake area is covered by Geological Survey of Canada Geophysical Series Maps 1492G and 1491G (GSC 1965a, 1965b) published at a scale of 1 inch to 1 mile (1:63 360).

The most prominent magnetic feature of the area is one circular anomaly with values greater than 3000 gammas surrounded by a larger zone with values of greater than 2500 gammas. This is located near Rib Lake in an area underlain by Archean mafic to ultramafic rocks. Similar anomalies occur several kilometres to the west in the Mountain Lake area (Born and Burbidge, *in press*) and immediately to the west of Kitt Lake. The latter appears to represent a buried Nipissing diabase sill beneath a thin veneer of arkoses of the Lorrain Formation. The sill dips to the south and becomes narrower to the east as it bifurcates into two dikes. Located on the northern limb of this sill are the Shakt-Davis Mine, Edison Mine and the Cobalt-Kittson Mine.

There are also several other circular anomalies with moderately high magnetic values of greater than 2500 gammas. One of these in the vicinity of Johnson Lake is directly underlain by Proterozoic Nipissing diabase. Other anomalies located in the vicinity of nearby Roosevelt Lake and Wilson Lake appear to be underlain by the sill buried beneath a thin veneer of arkose of the Lorrain Formation.

Elsewhere the isomagnetic contours are concentric to the main magnetic highs and accentuate and outline a general circular to subcircular pattern.

Several magnetic lows of less than 2000 gammas are also outlined by the survey. One occurs immediately to

the east of the Montreal River near the eastern map boundary and is mainly underlain by a Nipissing diabase sill intruding sediments of the Coleman Member of the Gowganda Formation. The spatial distribution of the low magnetic zone along the southern contact of the sill suggests that the sheet must dip in the opposite direction.

Other areas of low magnetic values are underlain by sediments of the Firstbrook Member of the Gowganda Formation in the vicinity of Slate Lake and to the west of Bay Lake at several localities. Close to these is another magnetic low located between the northern tip of Anima Nipissing Lake and Bay Lake. This area, however, is slightly different than the previous two in that it is underlain by arkoses of the Lorrain Formation.

The main feature of the regional gravity map (Gupta and Wadge 1980) is a gravity high located in the vicinity of the Cobalt-Kittson Mine along the northern boundary of the map area. Thus, this area has both high gravity and magnetic values. In contrast, a pronounced gravity low occurs in the Whitney Lake area adjacent to the southern margin of the map area. This area exhibits both a gravity high and a corresponding magnetic low. Elsewhere the isogravity contours trend in an east-west direction and illustrate a fairly steep gravity gradient between the two anomalies. Underlying the gravity high are arkoses of the Lorrain Formation cut by Nipissing diabase dikes. The data may indicate a large gabbro body at depth that is the feeder to the dikes. The area of low gravity is underlain by Archean granitoid rocks and metavolcanic rocks including some ultramafic intrusive and volcanic rocks (Smyk et al., *in press*).

Economic Geology

HISTORY OF MINERAL EXPLORATION

Local silver and cobalt exploration began following the discovery of silver in the Cobalt area in 1904. The Bay Lake map area is located about 8 km to the south of the original discovery site in the town of Cobalt.

Over 50 companies and individuals have carried out extensive exploration in the map area between 1906 and 1983. This work has included the sinking of 16 shafts with approximately 900 m of underground development; the completion of approximately 22 000 m of diamond drilling in 245 holes; and the blasting of numerous trenches and test pits on mineralized surface showings. A chronological list of previous exploration is given in Table 16 and the property list in Table 17. It is based on work reports on file at the Resident Geologist's office, Cobalt, Ontario and many of them are also available at the Assessment Files Research Office, Ontario Geological Survey. Another critical source of information is the Geological Data Inventory Folio (GDIF) for Gillies Limit Township (Ontario Geological Survey 1990).

MINERALIZATION ENVIRONMENTS

The general nature of silver mineralization in the vicinity of the Cobalt camp is best illustrated by the schematic diagram shown in Figure 25. Basically, the Early Proterozoic Nipissing diabase sills are a favourable host for fractures and veins filled by post-Nipissing silver mineralization. Repeated tectonic activity before, during and after the intrusions resulted in the generation and reactivation of regional-scale faults that acted as fluid pathways. This also resulted in rapid pressure release, boiling and/or degassing processes during the formation of the vein systems. Most veins are carbonate-rich and occur within a vertical distance of 200 m from the sill. The deposits are located at or near the Archean-Huronian unconformity. Vein systems are quite extensive but the ore grade mineralization is fairly restrictive and localized. Associated propylitic alteration in the wall rock surrounding the veins is indicative of highly alkaline fluids (Andrews et al. 1986). The source of mineralization is probably external to the immediate environment of deposition, with the majority of vein constituents being introduced with the fluids.

Abundant base metal sulphides hosted in the underlying Archean volcanics are a probable source of cobalt and silver mineralization in the Cobalt camp (Patterson 1979).

In the adjacent Coleman Member most of the rocks contain disseminated sulphides, some of which are primary and detrital in origin. This has been documented mainly in the Cobalt camp by Patterson (1979) within the

lower diamictite as well as syngenetic sulphides in the overlying mudstones. Vein-related sulphides occur in all rock types but most commonly in the sandstones. Detrital sulphides at both the Drummond and Silverfields mines are mineralized clasts and finely disseminated sulphides in the conglomerate matrix. Syngenetic sulphides occur as finely disseminated chalcopryrite, galena or sphalerite in mudstones at the Silverfields Mine. Deposition of detrital sulphides is probably controlled by paleovalleys in the Archean basement (Patterson 1979). The occurrence of sulphides in vein-related mineralization may also be controlled by local sulphides in the underlying Archean volcanics. In most instances disseminated sulphides occur adjacent to veins. Whether this mineralization predates or postdates the veins is commonly difficult to determine.

Copper, cobalt and silver are hosted in carbonate-rich veins that may contain various amounts of quartz and the following ore minerals: smaltite, cobaltite, gersdorffite, erythrite, annabergite, pyrite, chalcopryrite, argentite, bismuth, galena and niccolite. Others such as native silver and numerous sulpharsenides also occur but are rare.

Three types of veins, namely dilatant, shear and replacement, are common. Mineralization is typically discontinuous along any given vein structure. High-grade ore pockets commonly occur in the vicinity of vein intersections with late, shallow-dipping shear zones, lithologic contacts and abrupt changes (commonly fault controlled) in the configuration of the Archean basement topography (Andrews et al. 1986). Ore minerals occur in a wide variety of pods, bands, dendrites, plates and leaves, and zoned rosettes. Mineral zonation of silver and arsenides of iron, cobalt and nickel have been documented with individual vein systems but are locally variable (Andrews et al. 1986).

The lithologic characteristics of the 4 main deposit types of Cobalt and the Bay Lake area are shown in Figure 25 and described below.

Type 1 deposits occur within narrow Nipissing diabase dikes (70 to 140 m). Deposits of this type are not common in the original Cobalt mining camp itself but occur in the Bay Lake area. They consist of the Cobalt-Kittson Mine, the Shakt-Davis Mine and the Edison Mine, all located near the northwest corner of Coleman Township.

Type 2 deposits occur within the upper margins of the diabase sill. In the Cobalt camp no significant mineralization was ever discovered in the adjacent rocks above the upper margin of the sill.

Type 3 deposits occur within the lower margins of the diabase sill. Excellent examples of this are from the Cobalt camp itself (Langis, Silverfields and Pan Silver mines). Others include some of the very rich early producers with grades of greater than 5000 ounces Ag per ton (Andrews et al. 1986).

Table 16. Chronology of exploration work done in the Bay Lake area, District of Timiskaming. Current to 31/12/88.

Date	Company	Township	Location	Type of Work	Description	Comments
1907	Edison Mines Limited	Coleman	Conc.III, Lot 25	underground		
1909	Crown Jewels Mines Limited	Coleman	Conc.III, Lot 27	underground	7 cobalt-calcite veins	Shakt-Davis mine
1913	Bay Lake and Montreal River Mining and Development Company Limited	Coleman	Conc.III, Lots 19 and 20	trenching, stripping, underground	6 shafts in Nipissing diabase near the Lorrain sediment contact	
1916	Crescent Silver Cobalt Mining Limited	Coleman	Conc.III, Lot 27	underground	Shakt-Davis mine	work spanned the period 1916-24
1922	J. Burke	Gillies Limit	Block 16	trenching, underground	2 shafts in Archean volcanics	silver and cobalt mineralization in two vein systems
1924	D. Shone	Gillies Limit	Blocks 25 and 35	trenching, stripping	Hound Chute Lake area	native Au reported
1925	British Canada North Exploration and Development Company Limited	Gillies Limit	Block 43	geology, trenching, stripping, underground	2 shafts following several veins in Nipissing diabase	1 shaft-12 m, calcite vein with some Co and Ag
1925	Santa Maria Mines Limited	Gillies Limit	Blocks 22, 23 and 33	geology, magnetic, electromagnetic, resistivity, trenching, drilling	2 test pits 8 DDH-463m in 1946, 4 DDH-402m in 1951, 2 DDH-68m in 1960, 8 DDH-150m in 1967	work spanned period 1925-72, niccolite and calcite, 10-16% Co
1937	J. McGarry	Gillies Limit	Block 43	underground, drilling	near Hound Chute on the Montreal River	
1938	Shakt-Davis Mines Limited	Coleman	Conc.III, Lot 27	underground, drilling	winze-76m lateral-341m work-443m	work spanned the period 1938-51
1939	Fountain Falls Mining Syndicate	Gillies Limit	Block 54	underground	near Hound Chute on the Montreal River	
1946	Brewster Silver and Lead Syndicate	Gillies Limit	Blocks 11 and 29	drilling	5 DDH for 807m	minor HE, CP and PY mineralization
1947	Fairfax Mines Limited	Gillies Limit	Blocks 14, 15, 33 and 44	drilling	10 DDH-2163m	minor CP, PY, GA and PO
1947	Durex Mines Limited	Gillies Limit	Block 62	drilling	3 DDH-183m	minor CP, PY
1948	J. Price	Gillies Limit	Block 62	geology, drilling		
1950	Last Chance Mining Company Limited	Coleman	Conc.III, Lot 15.	underground	shaft sinking, 1 shaft 20m (min)	minor ER
1951	R. Sadler and A. LaPierre	Coleman	Conc.III, Lots 19 and 20	underground	1 shaft-30m with drifting on the 27m level	mineralization: 15 cm wide Co vein, 15.36% Co
1951	J. Price	Gillies Limit	Block 32	trenching		
1951	O'Brien Mines Limited	Gillies Limit	Block 32	underground, drilling	43m of tunnelling 2 DDH-98m	Co, ER
1951	Naneck Mines Limited	Gillies Limit	Block 53	drilling	6 DDH-292m	minor PY, CP, HE, ER and SP 0.04-1.07 oz Ag per ton 0.05-0.20 % Cu 0.39 % Zn
1951	Clark-Martin Property	Gillies Limit	Block 35	drilling	1 DDH-length unknown	ER

Table 16. (Continued)

Date	Company	Township	Location	Type of Work	Description	Comments
1952	Rib Lake Copper Mines Limited	Gillies Limit	Block 90	drilling	5 DDH-312m	minor mineralization PY, PE, PO, GA, HB and CP; assays: 0.2-1.3 oz Au per ton /1.7m; 0.05-1% Ni/1.5m
1952	J. Price	Coleman	Conc.IV, Lot 19	drilling	1 DDH-37m	CP 7.95% Cu and 1.96 oz Au per ton
1952	Nipissing Mining Company	Gillies Limit	Blocks 34 and 35	drilling	1 DDH-61m	
1952	Aunite Mining Company Limited	Gillies Limit	Blocks 34 and 35	drilling, trenching	3 DDH-unknown length	5 mineralized veins 0.38-1.7 oz Ag per ton 0.19-4.16% Co, and 0.31-8.02% Ni/9-50cm, trench samples: 0.44-60 oz per ton Ag, 0.89-12.18% Co, and 0.34-5.18% Ni
1952	Nickel Rim Mines Limited	Gillies Limit	Block 90	drilling	4 DDH-313m	minor CP mineralization grab sample 1.3 oz Au per ton
1953	Morgan-Everson Property	Gillies Limit	Block 59	trenching, drilling	number of holes uncertain	minor CP, PY, MT and HE
1953	Aconic Mining Corporation Limited	Coleman	Conc.III, Lot 27	underground, drilling		work spanned the period 1951-64 at the former Shakti-Davis mine
1953	Fleming Property	Gillies Limit	Blocks 14 and 22	drilling	20 DDH-1467m	minor CP, PY, GA, CO, AR and native Ag
1954	Johns-Manville Company Limited	Gillies Limit	Block 60	drilling	10 DDH-241m	minor PY, MO and CP
1955	E. Forebear	Gillies Limit	Blocks 34, 45 and 58	drilling	3 DDH-355m	minor CP and PY
1956	Crowpat Minerals Limited	Gillies Limit	Blocks 83, 84 and 91	drilling	15 DDH-142m	drilling in the SE corner of Block 84 hosted in Nipissing diabase with minor PY
1956	Coniagas Mines Limited	Gillies Limit	Blocks 91 and 83	drilling, magnetic, trenching, stripping	7 DDH-369m	minor PY, PO and Li mineralization, 0.05-1.7% Cu, and 0.03-0.51% Ni/1.5m
1956	Smaltite Silver Mining Co. Ltd.	Coleman	Conc.III, Lots 19 and 20	trenching, stripping		
1959	White Falcon Mines Limited	Gillies Limit	Blocks 14 and 22	resistivity, drilling	17 DDH-1456m	located to the west of Chopin Lake: minor CP, PY, GA, CO, AR and native Ag, 1.0 oz Ag per ton; 2.4 oz Ag per ton /8-18cm; and 90 oz Ag per ton /5cm
1959	Fairfax Mines Limited	Gillies Limit	Blocks 14 and 15	geology, drilling	15 DDH-2216m	minor CP, PY, GA, CO, AR and Ag values
1959	Rayrock Mines Limited (Plaskett Group)	Gillies Limit	Blocks 14, 16 and 22	resistivity, electromagnetic, drilling	22 DDH-1522m	minor CP, PY, PO, AR and native Ag
1960	Rayrock Mines Limited (Santa Maria Group)	Gillies Limit	Blocks 22, 23 and 33	drilling	4 DDH-567m	
1960	Botha Lake Mining Company Limited	Gillies Limit	Block 43	electromagnetic, drilling	16 DDH-1456m	located SE of Borden Lake, minor CP, PY, HE and MT mineralization
1961	Nickel Rim Mines Limited	Gillies Limit	Block 33	magnetic resistivity from core, drilling	16 DDH-1456m	located SE of Borden Lake minor CP, PY, HE and PO mineralization; from core 0.20 oz Ag per ton /5 cm; from sludge 0.60 oz Ag per ton /3 m

Table 16. (Continued)

Date	Company	Township	Location	Type of Work	Description	Comments
1962	Benner-Johnson East Property	Gillies Limit	Block 58	drilling	3 DDH-220m	minor PY, CP, HE and PO mineralization
1962	Glen Lake Silver Mines Limited	Gillies Limit	Block 48	drilling	7 DDH-765m	minor PY, CP, HE, MA and AN mineralization
1963	Goldray Mines Limited	Gillies Limit	Block 24	magnetic, resistivity, drilling	1 DDH-283m	minor CP, PY and HE mineralization in QZ + CC veins
1963	W. Shields	Gillies Limit	Block 53	drilling, underground	2 DDH-69m	minor PY, HE and ER mineralization
1963	Silver Tower Mines Limited	Gillies Limit	Blocks 26 and 36	drilling	1 DDH-214m	
1963	Nickel Rim Mines Limited (Whitney Lake Property)	Gillies Limit	Blocks 82, 84, 85, 90 and 96	resistivity, electromagnetic, magnetic, trenching, drilling	21 DDH-3585m	minor massive PO, CP and PY in some trenches, drill assays: 0.01-5.3 oz Ag per ton, 0.004-0.01 oz Au per ton, 0.03-0.38% Cu
1964	E. Rector	Gillies Limit	Block 68	drilling	7 DDH-203m	
1965	Silver Tower Mines Limited	Gillies Limit	Block 36	drilling	1 DDH-214m	
1965	Mentor Exploration & Development Co. Ltd.	Gillies Limit	Block 16	drilling	9 DDH-1072m	minor CP, PY, PO and HE
1965	Silver Gulf Mining and Development Ltd.	Gillies Limit	Block 25	drilling	5 DDH-465m	
1966	Ciglen Investments Limited	Gillies Limit	Blocks 53 and 62	drilling	20 DDH-770m	
1966	C. McConnell	Gillies Limit	Blocks 32, 33, 34, 43 and 45	drilling	10 DDH-380m	minor PY, CP and GA mineralization
1967	Ragged Chutes Silver Mines	Gillies Limit	Block 24	soil geochem		silver and cobalt anomaly (soil samples)
1968	Ryerson Mining and Development Limited	Gillies Limit	Blocks 14 and 22	drilling	9 DDH-950m	minor HE, PY and CP mineralization
1968	J. Price	Coleman	Conc. III, Lot 26	drilling	1 DDH-45m	
1968	Silver Monarch Mines Limited	Gillies Limit	Block 45	drilling	2 DDH-440m	minor PY, CP mineralization
1969	Murgor Exploration Limited	Gillies Limit	Blocks 34 and 35	drilling	6 DDH-638m	sludge assays: 0.06 oz Ag per ton minor Co mineralization in trenches
1970	Guardian Mines Limited	Coleman	Conc. IV, Lot 19	electromagnetic, magnetic		
1970	Dashota-Nipigon Mines Limited	Coleman	Conc. I, B, Lots 22 and 23	geological, magnetic, electromagnetic, trenching and stripping		located on Crowrock Bay of Anima Nipissing Lake: minor CP, PY, ER and HE mineralization in QZ + CC veins; grab assays: up to 7.0% Cu and 0.41% U ₃ O ₈
1971	A. Arseneault	Coleman	Conc. III, Lots 26 and 27	drilling	1 DDH-37m	
1971	Copperville Mining Corporation Limited	Gillies Limit	Blocks 59, 60 and 68	geological, magnetic, electromagnetic, drilling	5 DDH-647m	minor PY, CP, GA and PO mineralization; assays: 0.1-2.4 oz per ton Ag and 0.01-0.02% Cu/24cm
1971	Nickel Rim Mines Limited	Gillies Limit	Blocks 82, 84, 85, 90 and 96	drilling, magnetic, electromagnetic	3 DDH-493m	minor PY, CP, PO, MT and HE mineralization

Table 16. (Continued)

Date	Company	Township	Location	Type of Work	Description	Comments
1972	Lobo Mines and Exploration Limited	Gillies Limit	Blocks 58, 59 67 and 68	magnetic, electromagnetic, drilling	7 DDH-907m	minor PY, CP and Hk mineralization; assays: 0.02-0.11 oz Ag per ton
1972	E. Coy	Gillies Limit	Block 53	trenching		
1973	J. Zuzack	Gillies Limit	Block 24	trenching, drilling		minor disseminated CP
1974	BBH syndicate	Gillies Limit	Blocks 83 and 84	geology		
1982	Agnico-Eagle Mines Limited	Coleman	Conc. III, IV, Lots 18 to 24	electromagnetic, drilling	1 DDH-248m	Portage Bay area including Snake and Fiddler's Islands; minor PY mineralization

Abbreviations:

Ag	silver	CP	chalcopyrite	HE	hematite	PE	pentlandite
AN	annabergite	Cu	copper	Li	lithium	PO	pyrrhotite
AR	argenteite	DDH	diamond-drill hole	MA	malachite	PY	pyrite
Au	gold	ER	erythrite	MO	molybdenite	QZ	quartz
CC	calcite	GA	galena	MT	magnetite	SP	sphalerite
Co	cobalt	HB	homblende	Ni	nickel	Zn	zinc
CO	cobaltite						

Table 17. List of properties: former mines, occurrences and areas of past exploration of the Bay Lake area.

Number on map	PROPERTIES FORMER MINES
01	Edison Mine (Darby Mine)
02	Shakti-Davis Mine (Crescent Silver Mines Limited)
OCCURRENCES AND AREAS OF PAST EXPLORATION	
03	Agnico-Eagle Mines Limited [1982]
04	Bay Lake and Montreal River Mining and Development Company Limited [1913]
05	Brewster Silver and Lead Syndicate [1946]
06	Ciglen Investments Limited [1966]
07	Coperville Mining Corporation Limited [1971]
08	Fairfax Mines Limited [1947]
09	Goldray Mines Limited [1963]
10	Last Chance Mining Company Limited [1950]
11	Lobo Mines and Exploration Limited [1972]
12	C. McConnell [1968]
13	Murgor Exploration Limited [1969]
14	Nickel Rim Mines Limited (Block 33 Group) [1962]
15	Nickel Rim Mines Limited (Whitney-Rib Lake Group) [1971]
16	Rayrock Mines Limited (Santa Maria Group) [1960]
17	Ryerson Mining and Development Limited [1968]
18	Silver Tower Mines Limited [1963]
19	Silver Gulf Mining and Development Limited [1965]
20	Tashota-Nipigon Mines Limited [1970]
21	J. Zuzack [1971]

Type 4 deposits occur either within adjacent Archean volcanics and interflow sediments or sediments of the Coleman Member of the Gowganda Formation. The Beaver-Temiskaming and Silver Century mines

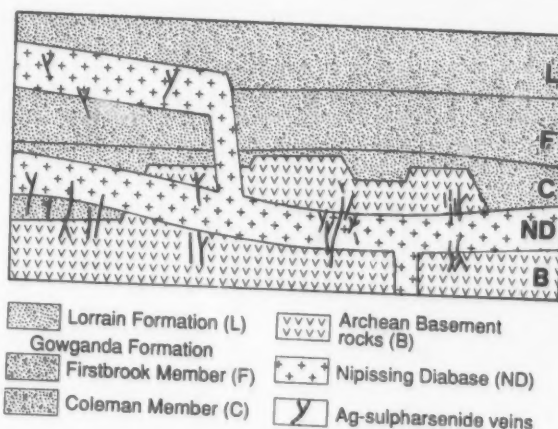


Figure 25. Simplified geological section showing the relationship between major lithologic units and the distribution of silver-sulpharsenide vein systems.

(Andrews et al. 1986) in Cobalt are of this type. The mineralization in adjacent rocks is spatially related and definitely linked to the diabase sills. Ore grades are highest in the host volcanic rocks and generally dissipate rapidly in the diabase.

Finally, there are some minor sulphide occurrences in the Bay Lake area that do not really belong to any of the above groups. These occurrences are also hosted in Archean metavolcanic rocks but are not spatially associated with the Nipissing diabase sills. It is believed that they represent either primary Archean volcanogenic sulphide mineralization or Archean shear-related and remobilized sulphides hosted within these rocks.

Table 18. Sample location list of UTM co-ordinates for geochemical data.
These are plotted on Figure 6.

Reference No.	Sample No.	UTM		
		ZONE	EASTING	NORTHING
01	0200*	17	602650	5241340
02	0281	17	595920	5230110
03	0288	17	602150	5240150
04	2230	17	602500	5239700
05	2290	17	603380	5235820
06	0302	17	592500	5235370
07	0056	17	592450	5235730
08	0306	17	592008	5235570
09	0307	17	592060	5235680
10	0398	17	602130	5239100
11	0423	17	602090	5238000
12	0410	17	601880	5238650
13	0419	17	602310	5238550
14	0273	17	602760	5241150
15	0315	17	591860	5235230
16	0009	17	595910	5237410
17	0041	17	591300	5238270
18	0049	17	592000	5236800
19	0352	17	603150	5236780
20	0322	17	591540	5236180
21	0045	17	591520	5237740
22	0006	17	595100	5238000
23	0100	17	592020	5245050
24	0123	17	586750	5244670
25	0187	17	583960	5243280
26	4119	17	592860	5241260
27	0016	17	597460	5237500
28	0035	17	600400	5233950
29	0106	17	598400	5239800
30	2075	17	596250	5230220
31	0056	17	592450	5235730
32	0071	17	593330	5233760

*All sample numbers are abbreviated from the standard Ontario Geological Survey sample numbers, e.g., 88PJB-0200.

On the following pages, a detailed description of the metal occurrences and their history of exploration activity are presented.

In the case of a known mineral deposit the occurrence is identified by a geographic name or a historically well-established name for that deposit.

In the case of ground on which there has been appreciable exploration activity, the parcels of land are listed under the name of the last company or individual to work that area. In this case the name will be followed by a date in square brackets representing the year in which that work was done.

The number in round brackets following the occurrence or parcel of land is the location number which is shown on the accompanying geological maps (Maps 2551, 2552; see back pocket) and listed in Table 18. In this table the individual and companies are listed and numbered in alphabetic order from 1 to 21. Listed below are the same Bay Lake area mineral occurrences subdivided into mineralization environments corresponding to Types 1, 2, 3, 4 and Archean mineralization.

The descriptions, if not otherwise stated, are based on data from assessment file reports or from field investigations undertaken by the authors during the 1988 field season. To the best of our knowledge all the information is current to December 31, 1988.

Type 1 Deposits

- 01 Edison Mine (Darby Mine)
- 02 Shakt-Davis Mine (Crescent Silver Mines Limited)

Type 2 Deposits

- 03 Agnico-Eagle Mines Limited [1982]
- 08 Fairfax Minerals Limited [1947]
- 10 Last Chance Mining Company Limited [1950]
- 13 Murgor Exploration Limited [1969]
- 20 Tashota-Nipigon Mines Limited [1970]
- 21 J. Zuzack [1971]

Type 3 Deposits

- 04 Bay Lake and Montreal River Mining and Development Company Limited [1913]
- 06 Ciglen Investments Limited [1966]
- 14 Nickel Rim Mines Limited (Block 33 Group) [1962]
- 19 Silver Gulf Mining and Development Limited [1965]

Type 4 Deposits

- 05 Brewster Silver and Lead Syndicate [1946]
- 07 Copperville Mining Corporation Limited [1971]
- 09 Goldray Mines Limited [1963]
- 11 Lobo Mines and Explorations Limited [1972]
- 12 C. McConnell [1968]
- 16 Rayrock Mines Limited (Santa Maria Group) [1960]
- 17 Ryerson Mining and Development Limited [1968]
- 18 Silver Tower Mines Limited [1963]

Archean Mineralization

- 15 Nickel Rim Mines Limited (Whitney-Rib Lake Group) [1971]

Description of Properties

TYPE 1 DEPOSITS: Cu, Co, Ag $\pm$ Au AND Ni MINERALIZATION HOSTED IN NARROW NIPISSING DIABASE DIKES

Two occurrences of this type, namely the Shakt-Davis Mine and the Edison Mine are located in the map area in the northwest corner of Coleman Township. These 2 deposits together with the nearby Cobalt-Kittson Mine (Born and Burbidge, in press) are all hosted in the same narrow, 70 to 140 m wide diabase dike. All 3 mines underwent development in the period 1906-40. Some of the better assays from here indicate a range of values up to 4% Co, 97 ounces Ag per ton and 3 ounces Au per ton.

Edison Mine (Darby Mine) (01)

The Edison Mine is located 1.2 km to the east of the Shakt-Davis Mine and occurs in the same narrow Nipissing diabase dike.

Similar parallel fractures to the diabase dike contain calcite veins with minor sulphide mineralization. Previous work includes 2 shafts, an adit and 2 underground levels. A crosscut on the Shakt-Davis Mine contains the Darby #4 vein which was intersected in a diamond-drill hole in 1951 at the Edison Mine. It consists of calcite stringers bordered by faults spaced 0.6 to 1.2 m apart with some cobaltite and smaltite. Drill results in 1 hole indicated 1.66% Co/0.24 m and 0.78% Co/0.76 m in a second hole.

GEOLOGY

The rocks in the vicinity of the mine consist of a 100 m wide Nipissing diabase dike locally intruding arkoses of the Lorrain Formation. Several calcite veins are hosted within the diabase dike at the Edison Mine. The veins dip 75° to the north and trend in a westerly direction. Samples from dump material indicate the presence of chalcopryrite, bornite, galena, erythrite and malachite hosted in coarse-grained calcite veins. Grab samples (Table 19) yielded values of 940 ppm Au, 17 ppm Ag, 3.09% Cu, and 3560 ppm Co (Geoscience Laboratories Section, Ontario Geological Survey, Toronto).

This occurrence is located some 1.5 km to the south of the Cobalt-Kittson Mine in adjacent Kittson Township (Born and Burbidge, in press) and 1.2 km east of the Shakt-Davis Mine. Thus, the same narrow (70 to 120 m) dike hosts all 3 deposits.

Shakt-Davis Mine (Crescent Silver Mines Limited) (02)

This deposit has been described by Born and Burbidge (in press) in the geological report of Brigstocke and Kittson townships. Thus, only a brief summary of the mineralization and geology is presented below.

This deposit is located on the northeastern shore of Kitt Lake and consists of several major calcite veins hosted in a fractured and faulted zone within a narrow

Nipissing diabase dike. The dike intrudes arkoses of the Lorrain Formation and laminated shaly mudstones of the Firstbrook Member of the Gowganda Formation. A fracture zone strikes 060°, parallel to the 120 m thick vertical dike. The "Main Vein" ranges in width from 1 to 7 m whereas the parallel "Chimney Vein" is from 1 to 3 m wide. Both are vertically oriented and contain smaltite, cobaltite, gersdorffite, erythrite (cobalt bloom), annabergite (nickel bloom), pyrite, chalcopryrite and niccolite. Assays and analyses indicated 1.5% Co and minor silver over a width of 1.37 m, with select grab samples indicating up to 4% Co and others with up to 2.72 ounces Au per ton. A further test of hand-picked ore indicated values of 0.87 ounce Au per ton, 0.25 ounce Ag per ton, 7.92% Co, and 7.72% Ni; another smaltite ore sample returned values of 97 ounces Ag per ton, 0.336% Co and 0.18% Ni (Assessment Files, Resident Geologist's office, Cobalt). Grab samples collected by the authors from the mine dump in 1987 yielded assay values of 0.10 ounce Au per ton, and less than 0.10 ounce Ag per ton, and values of 2480 ppm Co, 580 ppm Cu, and 7520 ppm Ni. Samples collected in the 1988 field season (Table 19) indicated values of 3560 ppm Co and 2% Cu (Geoscience Laboratories Section, Ontario Geological Survey, Toronto).

TYPE 2 DEPOSITS: Cu, Co, Ag ± Au AND Ni MINERALIZATION HOSTED IN UPPER MARGINS OF THE NIPISSING DIABASE SILL

Agnico-Eagle Mines Limited [1982] (03)

This occurrence is located along the south shore of Portage Bay in northwestern Coleman Township. The following is a summary of past exploration work.

The property was first discovered in 1912 and subsequent surface exploration consisted of at least 10 pits and shafts. A shipment of 50 tons of ore grading 16% Cu and 12 ounces per ton Ag was shipped in 1916.

Table 19. Assay values from grab samples collected during the 1988 season.

Sample No.	Reference No.	Cu ppm	Co ppm	Au ppb	Ag ppm	Ni ppm	Pb ppm
0298A	001A	2.01%	3560	940	17	-	-
0298B	001B	3.09%	2240	-	-	-	-
2215	002A	1130	2.14%	480	1740	-	-
2217A	002B	1.48%	-	-	20	-	-
2247A	003	7350	20	-	-	-	-
2219A	004	2600	6550	305	-	920	-
2297	005	780	3800	110	-	600	-
0056D	006	-	-	0.04*	< 0.10*	-	-
4002	007	530	-	210	< 2	-	-
0068A	008	6950	-	755	10	-	-
2039	009	1.41%	208	145	2	-	-
0274	0010	56	< 5	615	204	-	1.93%

Note: sample numbers correspond to location numbers on the map face; values in ppm or ppb unless otherwise indicated.

*Assay results reported in ounces per ton.

During 1952-59 J. Price initiated mineral exploration on the south shore of Portage Bay east of Jumbo Point (Table 16). One diamond-drill hole was completed in Nipissing diabase to a total depth of 37 m (122 feet). Notes by R. Thomson (Resident Geologist's files, Cobalt) indicate that a chalcopryrite vein exists with an approximate width of 1.5 m (5 feet) exposed in underground workings dating from 1929. Assay values include 7.95% Cu and 1.96 ounces Ag per ton (Resident Geologist's office, Cobalt).

The next period of local activity was in 1970 by Guardian Mines Limited (Table 16) on the Sutherland claims. A very low frequency electromagnetic (VLF-EM) ground survey delineated a number of small conductors as well as a large number of small fluctuations. The large conductors were interpreted to represent a possible mineralized fault zone whereas the smaller fluctuations might be vein conductors. A magnetic survey outlined 7 magnetic anomalies.

In 1982, Agnico-Eagle Mines Limited began exploration on a group of claims in the vicinity of Fiddler's and Snake islands on Portage Bay (Table 16). The claims covered an anomaly detected by a VLF geophysical survey. A single diamond-drill hole totalling 248 m (815 feet) was completed to test the geophysical anomaly. The hole intersected Nipissing diabase with quartz-calcite stringers and minor pyrite. However, no significant mineralization was encountered.

GEOLOGY

There are several mineralized occurrences along the south shore of Portage Bay. They are located within the upper contact zone of a Nipissing diabase sill that intrudes mudstone of the Firstbrook Member of the Gowganda Formation and arkoses of the Lorrain Formation. Mineralization generally consists of disseminated pyrite, chalcopryrite and malachite within quartz + calcite veins hosted in carbonatized varied textured Nipissing diabase. Grab samples (Table 19) taken from several old pits yielded values of 480 ppm Au, 7 ppm Ag, 1.48% Cu, 6550 ppm Co and 1740 ppm Ni (Geoscience Laboratories Section, Ontario Geological Survey, Toronto).

Fairfax Mines Limited [1947] (08)

This occurrence is located near Schumann Lake. Part of the work reported is actually to the north of the map area and was previously reported by Thomson (1961).

In 1922, J. Burke (Table 16) initiated exploration in Block 16 north of Schumann Lake (Thomson 1961). High-grade silver and cobalt mineralization hosted in Archean metavolcanics are exposed in a shaft at a depth of 11 m (38 feet). The 91 m (300 foot) shaft has levels at 30 m (98 feet), 62 m (204 feet) and 84 m (275 feet). On the 275-foot level a crosscut goes southward for 152 m (500 feet) and drifts were run off to the east and west 44 m (145 feet) from the shaft. Another vein traced by a series of trenches yielded assays of up to 100 ounces Ag per ton.

During the period 1947-59 Fairfax Mines Limited (Table 16) completed an exploration program around Schumann Lake. It consisted of 10 diamond-drill holes totalling 2163 m (7098 feet). Archean volcanics, Nipissing diabase and sediments of the Coleman Member of the Gowganda Formation were intersected. Minor sulphide mineralization including chalcopryrite, pyrite, galena and pyrrhotite occur together with heavy chlorite spotting in Archean volcanic rocks. Several trenches expose minor chalcopryrite mineralization in a few calcite veins along the north shore of Schumann Lake.

GEOLOGY

The rocks of the area consist of a locally fractured and possibly faulted Nipissing diabase sill. The mineralization occurs as disseminated sulphides, and in calcite veins located near the upper contact of the sill with pillowed Archean mafic flows. Barren quartz veins also occur and are abundant along the south shore of the lake.

Last Chance Mining Company Limited [1950] (10)

This property occurs along the Montreal River north of Latchford in Coleman Township. It has been examined and described by Thomson (1960).

Initial work began in 1910 with some shaft sinking on the property. Two cobalt-bearing veins and one chalcopryrite-bearing vein were explored by a 10 m (30 foot) vertical shaft. Calcite veins strike 085° and dip at angles which range from 80° at surface to about 58° at the bottom of the shaft. The veins are hosted in a fractured and sheared zone in the Nipissing diabase. Mineralization consists of pyrite, chalcopryrite and erythrite.

The nearby Van Chester veins are located on the east shore of the Montreal River opposite the Last Chance occurrence. They were discovered in 1955. A shaft and several pits expose several east-trending and vertically oriented, mineralized calcite and quartz veins hosted in Nipissing diabase. In the No. 2 veins, erythrite and minor galena occur within pink calcite veins up to 5 cm (2 inches) wide. The nearby No. 3 vein consists of 60 cm (2 feet) wide quartz veins containing minor amounts of chalcopryrite with lesser sphalerite and galena.

GEOLOGY

The Last Chance occurrence is located within the upper part of a Nipissing diabase sill along the Gowganda-Lorrain contact. Analyses of samples of the pyrite-, erythrite- and annabergite-bearing calcite vein material resulted in values of 780 ppb Cu, 3800 ppm Co and 600 ppm Ni (Table 19; Geoscience Laboratories Section, Ontario Geological Survey, Toronto).

Murgor Exploration Limited [1969] (13)

Extensive exploration has been carried out on this property in the past. In 1924-25, D. Shone carried out extensive stripping and trenching operations (Table 16) east of

Hound Chute Lake. Results from this work include the discovery of some native gold (Notes by R. Thomson, Resident Geologist's files, Cobalt).

Subsequent work in 1951 consisted of a single diamond-drill hole below a pit with cobalt mineralization on the Clark-Martin claims (Table 16).

Aunite Mining Corporation Limited (Table 16) did some minor trenching and several short diamond-drill holes in 1951. The pits exposed five mineralization zones including an 8 cm wide, massive smaltite vein and Nipissing aplite vein with erythrite. Assay values range up to 0.5 ounce Ag per ton, 12.18% Co and 4.14% Ni over a width of 7.6 cm (3 inches).

In 1955, E. Forbear drilled 3 diamond-drill holes (Table 16) totalling 355 m (1164 feet). The drill holes encountered Huronian sediments and some Archean granites with minor disseminated pyrite and chalcopyrite.

Follow-up drilling in the area by Armstrong and Watts in 1962 consisted of 2 holes totalling 73 m. Minor hematite and pyrite mineralization were encountered.

In 1968 Silver Monarch Mines Limited drilled 2 diamond-drill holes for a total length of 1440 feet (439 m). Minor occurrences of chalcopyrite and pyrite were reported.

Murgor Exploration Limited also carried out an exploration program in the vicinity of Hound Chute. In 1969, Murgor Exploration completed a 6-hole diamond-drill program totalling 638 m (2092 feet) to further explore and develop the cobalt occurrence. The holes intersected mainly Nipissing diabase and sedimentary rocks of the Coleman Member of the Gowganda Formation. Assay values from 5 sludge samples range from trace amounts to 0.6 ounce Ag per ton.

GEOLOGY

Exposure around Hound Chute on the Montreal River is poor. There are only a few outcrops of varied textured Nipissing diabase cut by minor granophyre veins. These rock types are characteristic of the upper portions of the sill that underlies nearby sediments of the Coleman Member. Any of the mineralization reported near the water level is now flooded due to a dam on the Montreal River at The Notch. All other reported mineralization is at depth and was reported from diamond-drill results.

Tashota-Nipigon Mines Limited [1970] (20)

This occurrence straddles the Kittson-Coleman townships boundary near Crowrock Bay of Anima Nipissing Lake and has been described in detail by Born and Burbidge (in press). A brief summary is given below.

During 1970, Tashota-Nipigon Mines Limited carried out an extensive exploration program in the Crowrock Bay area of Anima Nipissing Lake in northeastern Brigstocke and western Coleman townships. It consisted of geological, geochemical and ground electromagnetic and magnetic surveys, and trenching and stripping in an area which had been previously prospected in the early 1900s. The geological setting is similar to several other occurrences found along the upper margins of the Nipissing diabase sill with common varied textured diabase and granophyre dikes. Several minor quartz-calcite veins (2 to 10 cm wide) contain disseminated chalcopyrite, pyrite and erythrite hosted in the uppermost part of the sill. Assays from trench grab samples indicate values up to 7.0% Cu and 0.41% U_2O_8 (Born and Burbidge, in press).

J. Zuzack [1971] (21)

This occurrence is located along the Montreal River, west of Darwin Lake.

The earliest work was by Durex Mines in 1947 (Table 16) and it consisted of 183 m (601 feet) of diamond drilling of 3 holes. Only minor pyrite mineralization was intersected in 1 of the holes.

Later work consisted of a single drill hole by K. Home in 1963. The hole was 35 m (115 feet) long and intersected minor chalcopyrite, pyrite and arsenopyrite.

In 1965, Mentor Exploration & Development Company Limited (Table 16) completed a 9-hole diamond-drill program totalling 1072 m (3517 feet). Low silver values and minor amounts of chalcopyrite, pyrite, pyrrhotite and hematite were encountered in the drill holes.

Geological and geochemical surveys were completed over the property in 1967 by the Ragged Chutes Silver Mines Limited (Table 16). Results from the surveys were negative and failed to outline any cobalt or silver mineralization.

John Zuzack (Table 16) did some limited trenching and diamond drilling on the property in 1973. The recoverable core consisted of medium-grained, varied textured Nipissing diabase and granophyre with minor disseminated blebs of chalcopyrite (notes by R. Thomson, Resident Geologist's files, Cobalt).

GEOLOGY

Minor sulphide mineralization occurs near the top of the Nipissing diabase sill in contact with arkoses of the Coleman Member of the Gowganda Formation. The Montreal River Fault transects the property and probably plays an important role in determining fracture patterns and mineralization within the diabase at this locality.

TYPE 3 DEPOSITS: Cu, Co, Ag $\pm$ Au AND Ni MINERALIZATION HOSTED IN LOWER MARGINS OF THE NIPISSING DIABASE SILL

Bay Lake and Montreal River Mining and Development Company Limited [1913] (04)

This property is located on the eastern shore of Bay Lake in Coleman Township, Concession III, Lots 19 and 20. The greatest amount of work was completed in 1913 by the Bay Lake and Montreal River Mining and Development Company Limited (Table 16). It consisted of 6 shafts in Nipissing diabase and extensive stripping of the Nipissing diabase-Lorrain sediment contact.

During the period 1923-34, Nipissing Mining Company Limited trenched and stripped a portion of the property and completed an unknown amount of subsequent underground development.

In 1951, Sadler and La Pierre (Table 16) completed 30 m (100 feet) of shaft sinking and 30 m (100 feet) of drifting on the 27 m (90-foot) level. At this level the drifting exposed a 15 cm (6 inch) wide massive cobaltite-rich vein. Samples produced assays in the order of 15.36% Co (notes by R. Thomson, Resident Geologist's files, Cobalt). No diamond drilling was reported from this property.

In 1956, some minor trenching, prospecting and geological mapping was completed about 1600 m to the south of the shafts by the Smaltite Silver Mining Company Limited. No significant mineralization was discovered and the trenches are now all infilled and in poor condition.

GEOLOGY

Several calcite veins occur within the lower part of a Nipissing diabase sill near the contact with arkoses of the Lorrain Formation. Grab samples of dump material with disseminated pyrite, chalcopyrite, malachite and erythrite (Table 19) taken in 1988 by the authors, yielded assay values of 2600 ppm Cu, 6550 ppm Co, 305 ppb Au, and 920 ppm Ni (Geoscience Laboratories Section, Ontario Geological Survey, Toronto).

Ciglen Investments Limited [1966] (06)

This prospect is located to the east of the Montreal River near the township boundary with Lorrain Township.

The earliest work was completed in 1947 by Durex Mines Limited (Table 16). It consisted of some geological mapping and a 3-hole diamond-drill program totalling 183 m (601 feet). Only minor pyrite mineralization was encountered.

During 1951 subsequent work was done by J. Price and Nancek Mines Limited (Table 16). The exploration work done by Nancek Mines Limited consisted of a diamond-drill program of 6 holes totalling 292 m (958 feet).

The drill data indicated mafic, intermediate and felsic volcanic rock types with minor pyrite, chalcopyrite, specularite, hematite, erythrite and sphalerite mineralization. Assay values included 0.04 to 1.07 ounces Ag per ton, 0.05 to 0.2 ounce Cu per ton and 0.39 ounce Zn per ton.

In 1963, W. Shields (Table 16) completed a shallow 12 m (38 feet) shaft on the property (notes by R. Thomson, Resident Geologist's files, Cobalt). Two diamond-drill holes were completed for a total length of 69 m (227 feet) with no sulphides in either hole. Rare local mineralization exposed in a nearby creek consists of some erythrite in Coleman Member conglomerates and specular hematite in Archean volcanic rocks (notes by R. Thomson, Resident Geologist's files, Cobalt).

In 1966, Ciglen Investments Limited carried out extensive exploration on the property. The program consisted of 20 diamond-drill holes for a total of 770 m (3528 feet). Various Nipissing rock types and minor, barren, 1 cm wide calcite stringers were intersected. No assay data is available for any of these holes.

In 1972, subsequent but minor trenching was carried out by E. Coy. No significant mineralization was discovered.

GEOLOGY

The mineralization is hosted in the middle or lower part of Nipissing diabase sills that intrude sediments of the Coleman Member of the Gowganda Formation. The host rocks are typical quartz diabase and fine-grained, chilled quartz diabase without any apparent local alteration. During the 1988 field season no signs of significant veining or sulphide mineralization were discovered. All previous reported mineralization is from drill hole data.

Although the drill-indicated mineralization is minor, it does indicate the presence of some minor sulphides at depth at a few localities.

Nickel Rim Mines Limited (Block 33 Group) [1962] (14)

This former property is located to the southeast of Darwin Lake in the northeastern part of the Bay Lake area.

During the period 1961-65, Nickel Rim Mines Limited (Table 16) embarked upon an exploration program which consisted of magnetic and resistivity geophysical surveys followed by a diamond-drill program of 16 holes totalling 1456 m. Three of these holes totalling 614 m (2014 feet) are within the map area. Three north-trending geophysical anomalies were identified and later drilled. Mineralization encountered included chalcopyrite, pyrite, hematite and pyrrhotite hosted in Nipissing diabase. Assay values represent both core and sludge samples and include 0.20 ounce Ag per ton over an average width of 5.0 cm (2 inches) from core samples and 0.10 to 0.60 ounce Ag per ton over an average width of 3 m (10 feet) from sludge samples.

Previous exploration work on this parcel of ground also includes some overlap from adjacent properties.

This includes some diamond drilling by Fairfax Mines in 1947 and by Rayrock Mines in 1960.

GEOLOGY

Similar to other occurrences of this type, it is hosted in the lower part of a Nipissing diabase sill. The rocks consist mainly of unaltered, medium- to coarse-grained quartz diabase with no surface indications of calcite or quartz veins or any substantial concentrations of sulphides. The drill results, however, indicate that there are local disseminated concentrations of sulphides at depth throughout the area. The geophysical results indicate anomalous zones of low resistivity that may represent significant target zones for future drilling.

Silver Gulf Mining and Development Limited [1965] (19)

This property is located in an area to the northeast of Hound Chute Lake and to the west of the Montreal River.

Diamond drilling on this property was first completed by Silver Gulf Mining and Development Limited in 1965. The program consisted of 5 drill holes for a total length of 465 m (1525 feet). The purpose of the program was to investigate the down-dip extension of several cobaltite- and niccolite-bearing calcite veins exposed in surface trenches. Relatively unaltered Nipissing diabase, Archean tuffs and an altered shear zone were the rock types intersected in various drill holes. Results from the drill program indicated several calcite stringers hosted in relatively unaltered Nipissing diabase and the underlying Archean volcanic rocks. Assay results range from nil to 0.4 ounce Ag per ton.

GEOLOGY

The occurrence is located at the base of a Nipissing diabase sill in contact with Archean mafic metavolcanic flows. Minor copper and cobalt mineralization hosted in several calcite veins within the diabase are exposed in a shaft and several surface trenches.

TYPE 4 DEPOSITS: Cu, Co, Ag $\pm$ Au AND Ni MINERALIZATION HOSTED WITHIN ARCHEAN VOLCANICS AND INTERFLOW SEDIMENTS AND SEDIMENTS OF THE GOWGANDA FORMATION ADJACENT TO NIPISSING DIABASE SILLS

Brewster Silver and Lead Syndicate [1946] (05)

In 1946, Brewster Silver and Lead Syndicate (Table 16), completed a diamond-drill program consisting of 5 holes totalling 807 m (2649 feet). Wackes, conglomerates, diabase and a fault and/or shear zone were intersected in the drill holes. Mineralization included hematite, chalcopryrite and pyrite.

GEOLOGY

This area is underlain by laminated siltstones of the Firstbrook Member of the Gowganda Formation. The location of some of the drill holes is close to the contact with arkoses of the overlying Lorrain Formation. The closest exposed diabase sill is 4 km to the north along the Montreal River. Otherwise there are no diabase rocks in the area, thus the exact nature of the drill targets is uncertain. Results from the drill program did, however, intersect a fault zone in several holes. This probably represents a parallel fault to the main Latchford Fault located some 600 m to the west.

Copperville Mining Corporation Limited [1971] (07)

This occurrence is located in an area east of Island Lake and to the west of Highway 11 in the southern part of the Bay Lake area.

In 1953, initial work in the area began on the Morgan-Everson property (Table 16). Notes by R. Thomson (Resident Geologist's files, Cobalt) indicate a trench sample of vein material consisted largely of chalcopryrite, some pyrite, magnetite and specular hematite. Some diamond drilling was reported but little else was done.

In 1954, Johns-Manville and Bruneau Brothers did some exploration in the same area. It consisted of 10 diamond-drill holes for a total length of 241 m (892 feet). Minor pyrite mineralization was encountered in each hole, with minor molybdenum and chalcopryrite in several holes.

In 1971, the Copperville Mining Corporation Limited (Table 16) carried out an extensive exploration program consisting of geological, magnetic and electromagnetic geophysical surveys and subsequent diamond drilling. A total of 30 line kilometers (18.7 line miles) of grid covered the property.

The VLF-EM survey delineated 2 southeast-trending, anomalous zones on the western margin of the property. These zones were believed to be due to mineralized shear zones in the underlying bedrock. The subsequent magnetic survey was completed, however, there is poor correlation between the VLF conductive zones and magnetic anomalies. Five diamond-drill holes totalling 674 m (2212 feet) were completed in both Archean volcanic and Nipissing diabase rocks. Mineralization included minor chalcopryrite, galena, pyrite and pyrrhotite. Assays indicated 0.1 to 2.4 ounces Ag per ton over an average width of 24 cm (9.4 inches) and 0.01 to 0.02% Cu.

GEOLOGY

Local sulphide occurrences are hosted in Archean mafic volcanics and migmatized volcanic material. Intercalated with these are some minor felsic to intermediate volcanic rocks, some of which are pyroclastic in origin. The nature of some of the mineralization is rather massive and possibly suggestive of volcanogenic massive sul-

phides containing minor pyrite and chalcopyrite. Grab samples taken by the authors from some trenches in 1988 (Table 19) indicated only low assay values of 530 ppm Cu, 210 ppb Au and less than 2 ppm Ag (Geoscience Laboratories Section, Ontario Geological Survey, Toronto). The basal zone of a Nipissing diabase sill intrudes the Archean sequence 200 m south of the showing. Whether the diabase had a significant role during mineralization is uncertain. If it did not, then these occurrences could be considered as sulphide mineralization hosted in Archean volcanics. However, the spatial proximity of the diabase sill probably represents a contributing factor that controls mineralization in the area. All of these factors together with the presence of several conductive zones suggest that the area is a good exploration target.

Goldray Mines Limited [1963] (09)

This area is located on the east side of Darwin Lake along the northern margin of the Bay Lake map area.

In 1963, Goldray Mines Limited carried out magnetic and resistivity geophysical surveys which delineated 1 north-trending conductor under Darwin Lake. One diamond-drill hole beneath the conductor was completed to a total depth of 283 m (930 feet) and indicated highly fractured Huronian sedimentary rocks with minor chalcopyrite, pyrite and specularite in quartz-calcite vein systems. Minor chlorite spotting occurred in the sediments.

GEOLOGY

There is little outcrop in the drill hole area. The surrounding area is underlain by mudstones and arenites of the Coleman Member of the Gowganda Formation. The drill-indicated mineralization is located 100 m to the west of the lower contact of a Nipissing diabase sill. The proximity of the sill, nearby mafic volcanics to the north, and the nearby Montreal River Fault Zone to the west were probable contributing factors to local sulphide mineralization. With all of these positive factors, more mineralization may occur at depth in this area.

Lobo Mines and Explorations Limited [1972] (11)

This area is located on both east and west sides of Johnson Lake, just east of Highway 11 in the southern part of the map area.

Work in the area began in 1962 with exploration on the Benner-Johnson East property (Table 16). The exploration program consisted of 3 diamond-drill holes totalling 220 m (722 feet). Minor pyrite, chalcopyrite, specular hematite, hematite and pyrrhotite mineralization was encountered.

During 1962, Glen Lake Silver Mines Limited (Table 16) also carried on mineral exploration on a nearby property located south of Hears Lake in Block 48 of Gillies Limit Township. The diamond-drill pro-

gram consisted of 7 holes with a total length of 765 m (2511 feet). Only minor pyrite within sediments of the Coleman Member were encountered. Three subsequent holes completed in 1968 contained more significant mineralization consisting of minor chalcopyrite, pyrite, annabergite, malachite and hematite. No assay values are given for these drill holes.

In 1964, E. Rector (Table 16) completed a diamond-drill program consisting of 7 holes totalling 203 m (666.4 feet). The location of the drill holes is approximately 1.5 km to the southwest of Johnson Lake and in an area underlain by Nipissing diabase rocks. Results from the drilling indicated that only basic igneous rocks representing presumable Nipissing diabase were intersected. No mineralization was reported from the recovered core. A small amount of trenching did not reveal any new mineralization.

In 1971, Lobo Mines and Explorations Limited (Table 16) carried out an extensive exploration program around Johnson Lake. It included magnetic and electromagnetic geophysical surveys and a diamond drilling program. A total of 28 km (17.47 miles) of VLF-EM surveys outlined extensive fracturing of the northwest-trending Latchford fault system under Johnson Lake. In addition to the major conductive zone, 3 smaller zones were detected that possibly represent an east-west fracture system. Four drill targets were recommended to test the various electromagnetic (VLF) conductors. Results from the magnetic survey did not outline any magnetic anomalies. Seven diamond-drill holes totalling 907 m (2977 feet) were completed. Mineralization encountered included minor pyrite and chalcopyrite. Assay results indicated 0.02 to 0.11 ounce Ag per ton. At least one of the drill holes intersected a conductive zone that probably corresponds to the Latchford Fault under Johnson Lake.

GEOLOGY

Mineralization intersected in the area occurs both within the upper parts of a Nipissing diabase sill and adjacent conglomerates of the Coleman Member of the Gowganda Formation. Some mineralization also occurs along the contact between the 2 lithologic units and was intersected in drill holes and observed on surface. On surface it occurs as disseminated galena within conglomerates along the railway at the south end of Johnson Lake. This zone has undergone contact metamorphism and intense local chloritization adjacent to the upper part of the diabase sill. Some mineralization may also be associated with several fractured and faulted zones that represent the Latchford Fault. A precise correlation of this is rather tenuous and based on extrapolation of a few scattered drill results. However, this is probably a key target zone in the area. Several surface sulphide showings occur in sheared, varied textured Nipissing diabase along Highway 11 west of Johnson Lake. Minor hydrothermal alteration is associated with several vertically oriented, 2 to 4 cm quartz veins that contain minor pyrite, pyrrhotite and chalcopyrite. Further to the east similar mineralization occurs as disseminated pyrite, chalcopyrite and

malachite in several narrow (2 to 4 cm wide), vertically oriented quartz veins. The host rocks also appear weakly altered, well jointed and/or slightly faulted as at the roadcut occurrence. Grab samples taken by the authors from these showings in 1988 indicate values of 1.41% Cu, 208 ppm Co, 145 ppb Au and 2 ppm Ag; and 6950 ppm Cu, 755 ppb Au and 10 ppm Ag (Table 19; Geoscience Laboratories Section, Ontario Geological Survey, Toronto).

C. McConnell [1968] (12)

This former property is located in an area southeast of the Hound Chute Dam, both on the east side of the Montreal River and further to the east along the eastern boundary of the map area.

In 1925, British Canada North Exploration and Development Company Limited (Table 16) began an exploration program with geological mapping and subsequent trenching and stripping. This was followed by the sinking of 2 shafts on a network of mineralized veins.

Later work by J. Price in 1951 (Table 16) consisted of some trenching near the eastern boundary of Gillies Limit Township. O'Brien Mines (Table 16) optioned the property and completed a tunnel approximately 43 m (140 feet) long. Two diamond-drill holes totalling 98 m (322 feet) were drilled to test the extent of the vein network consisting of a series of white to grey calcite-filled fractures in Nipissing diabase. Grey cobalt-arsenides, erythrite and native silver occurs in the 2 cm wide vein system. In the tunnel, Archean volcanic rocks above the Nipissing diabase display contact metamorphic features (notes by R. Thomson, Resident Geologist's files, Cobalt).

During the period between 1960 and 1961, Botha Lake Mining Company Limited (Table 16) carried out an electromagnetic (radiograph) geophysical survey and subsequent diamond-drill program consisting of 16 holes totalling 1456 m (4776 feet). The drill program intersected mostly Archean volcanic rocks and Nipissing diabase. Mineralization included minor chalcopryrite, pyrite, hematite and magnetite.

During the period between 1966 and 1970, Craig McConnell (Table 16) carried out a diamond-drill exploration program consisting of 10 holes totalling 380 m (1247 feet). Mineralization intersected includes minor pyrite, chalcopryrite and galena in predominantly Nipissing diabase and Huronian sedimentary rock of the Coleman Member of the Gowganda Formation.

GEOLOGY

The former McConnell property covers a large and diverse geological terrain in the northeastern part of the map area. Drill holes have been collared in Nipissing diabase, conglomerates and other sediments of the Coleman Member of the Gowganda Formation and Archean mafic and felsic volcanic rocks. Generally, the geological environment is most favourable and the best assays come from areas underlain by Archean metavol-

canics near the diabase contact. At surface there are numerous sulphide showings. Numerous other drill-indicated mineralized zones also exist at depth. The real question in this area is whether all the mineralization is of the disseminated variety or could some previously undiscovered and significant concentrations occur at depth. Also note that all of the mineralization may not be related to the Nipissing diabase but could represent volcanogenic massive sulphides within felsic pyroclastic rocks. The mineral potential of this area is good, and further exploration is recommended.

Rayrock Mines Limited (Santa Maria Group) [1960] (16)

This area is located along the eastern border of Gillies Limit Township just to the northeast of Borden Lake.

During the period 1925-72, Santa Maria Mines Limited (Table 16) carried out an extensive exploration program of geological, magnetic, electromagnetic and resistivity surveys. Two test pits were sunk. They exposed niccolite and cobaltite mineralization in calcite veins with average grades of between 10 and 16% cobalt. Extensive trenching also exposed other unmineralized quartz-calcite veins. In 1946, Santa Maria Mines Limited completed 8 diamond-drill holes totalling 463 m (1520 feet). All holes intersected Archean volcanic rocks and minor lamprophyre dikes with mineralization concentrated in quartz-calcite veins. In 1951 Santa Maria Mines Limited completed 4 diamond-drill holes totalling 402 m (1319 feet) with only minor sulphide and arsenide mineralization in some of the holes.

In 1960, another 4 diamond-drill holes completed on the property by Rayrock Mines Limited totalled 567 m (1859 feet). In 1960, Santa Maria Mines Limited drilled 2 holes totalling 68 m (223 feet) and encountered Archean volcanic rocks with diabase and Proterozoic Coleman Member conglomerates, respectively. Subsequently in 1967, another 2 holes were drilled to a total depth of 150 m (491 feet). Minor chalcopryrite, pyrite and hematite mineralization were intersected in these holes.

GEOLOGY

One of the most important finds on the former Santa Maria Mines Limited property was a spectacular silver float boulder found in 1934 called the "Silver Nugget". It contained 11 000 ounces of silver and is now on display in the Legislature Building at Queen's Park, Toronto. Much of the subsequent exploration activity was an effort to find the source of the boulder. The probable source for the boulder is the main Cobalt mining camp. Glaciers probably plucked the boulder and transported it in a down-ice direction to the discovery site. However, there are also sulphide occurrences hosted in the local Archean rocks. Most of these are definitely related to the nearby upper contact of the Nipissing diabase sill and contain typical cobalt- and arsenide-rich sulphides. Several of the local conductive zones have never been drilled and represent potential drill targets of unknown resources. The local Archean rocks mainly consist of

mafic flows with some minor intercalated felsic pyroclastic rocks. The occurrences in these rocks are in variably silicified and chloritized basalts with disseminated pyrite, chalcopyrite and bornite. Nearby felsic rocks could also represent a zone for possible sulphide mineralization. Some of the pyroclastic flows actually contain minor sulphide fragments which probably represent primary volcanogenic mineralization. The alteration patterns of variable silicification, chloritization and associated carbonatization are also typical of potential mineralized Archean volcanogenic sulphide terrains.

Ryerson Mining and Development Limited [1968] (17)

The area investigated by this company is located in the extreme northeast corner of the Bay Lake map area, to the west of Chopin Lake.

The initial work was in 1953 on the Fleming property (Table 16). It consisted of an extensive diamond drilling program of 20 holes totalling 1467 m (4812 feet). Minor pyrite, chalcopyrite, galena, cobaltite, argentite and native silver mineralization was encountered.

Subsequent work by White Falcon Mines Limited (Table 16) included some trenching of several mineralized veins at the south end of Chopin Lake. In 1959, a radiograph resistivity survey was completed and delineated a number of strong anomalies. Follow-up diamond drilling consisted of 17 holes totalling 1456 m (4777 feet). Archean volcanics, Nipissing diabase and some unidentified sedimentary rocks were intersected. Drilling of 1 of the 2 northwest-trending geophysical anomalies southwest of Chopin Lake intersected a mineralized calcite vein 7.62 to 17.78 cm (3 to 7 inches) wide that returned assay values of up to 1.0 ounce Ag per ton. The drilling of one of the north-trending anomalies 274 m (900 feet) west of Chopin Lake, showed a well-mineralized calcite vein in Archean metavolcanics near the diabase contact. Assay results indicated values of 2.4 ounces Ag per ton. Drill intersections under the strongest north-trending anomaly, indicated extensive veining across widths up to 3 m (10 feet) with erratic silver assay values up to 90 ounces Ag per ton. Geological interpretations based on local mapping indicated deposits similar to those in the Cobalt camp with narrow sulphide-bearing carbonate veins and fracture zones hosted in Archean mafic flows.

In 1959, Rayrock Mines Limited (Plaskett Group) (Table 16) completed resistivity and electromagnetic (radiograph) geophysical surveys. A subsequent diamond-drill program consisting of 22 holes totalling 1522 m (4995 feet) was carried out. Minor pyrite, chalcopyrite, pyrrhotite, argentite and native silver mineralization was reported.

In 1968 Ryerson Mining and Development Limited completed a diamond-drill program consisting of 9 holes totalling 950 m (3000 feet). Minor hematite, chalcopyrite and pyrite were encountered in all holes. The mineralized sections were assayed for silver but no values were reported.

GEOLOGY

This is another area recommended for further exploration. The rocks around the occurrences consist of pillowed, Archean mafic flows of a komatiitic basalt composition intercalated with some calc-alkalic and plagioclase-phyric andesites.

Extensive chloritization and carbonatization occurs locally within the Archean pillowed mafic flows. Recorded mineralization occurs both at the contact of mafic flows with Archean granites to the east, and along the contact of mafic flows with the upper margins of the younger Nipissing diabase to the west. Several drill intersections along the later contact indicate the presence of silver mineralization with assay values of up to 90 ounces Ag per ton. In this case the typical silver mineralization is definitely associated with the underlying Nipissing diabase sill although it is hosted in older Archean volcanic flows. Another factor controlling mineralization could be a local fault as expressed by some strong lineaments in the area and underneath the Chopin Lake area. They could have localized calcite veins and associated mineralization.

Silver Tower Mines Limited [1963] (18)

This former property is located in the Hound Chute Lake area in the central part of the Bay Lake map area.

In 1963, Silver Tower Mines Limited (Table 16) completed geological mapping and 1 diamond-drill hole totalling 214 m (703 feet). The drill hole is located approximately 130 m (430 feet) northwest of Hound Chute Lake. Unmineralized sediments of the Firstbrook Member and Coleman Member of the Gowganda Formation were intersected.

GEOLOGY

Local sediments of the Gowganda Formation consist of conglomerates of the Coleman Member overlain by mudstones of the Firstbrook Member. These are in turn overlain by arkoses of the Lorrain Formation and intruded by a major Nipissing diabase sill in the vicinity of Hound Chute Lake. No known surface mineralization occurs in the sediments, however, there is one chalcopyrite-bearing quartz vein at the base of the nearby Nipissing diabase sill.

ARCHEAN MINERALIZATION: SULPHIDE MINERALIZATION HOSTED IN ARCHEAN METAVOLCANICS BUT UNRELATED TO EARLY PROTEROZOIC NIPISSING DIABASE SILLS

Nickel Rim Mines Limited (Whitney-Rib Lake Group) [1972] (15)

This area investigated by Nickel Rim Mines Limited is located along the southern margin of the Bay Lake map area.

In 1952, exploration in the Whitney Lake-Rib Lake area was initiated by Rib Lake Copper Mines Limited

(Table 16). It consisted of a 5-hole diamond-drill program totalling 297 m (1025 feet). These holes were drilled east of Highway 11 and 200 m to the south of the map area in Block 90 of Gillies Limit Township. Various Archean tuffs and wackes, feldspar porphyries, mafic flows, hydrothermal alteration zones and scattered sulphides were intersected in these holes. The sulphides consist mainly of disseminated pyrrhotite, pyrite, niccolite and possibly temiskamite (Ni_3As_2). The most important intersection was in hole No. 4 which intersected a 4.0 m (13-foot) thick zone of silicified and sheared tuffs with 5% pyrrhotite and minor pyrite. Assay samples returned values of 1.30 ounces per ton Au and 0.89% Ni over a width of 1.83 m (6 feet). However, since the first 2.13 m (7 feet) were not split, the values may well represent a 4 m section (13 feet) of high gold values. Another intersection of mafic intrusive rocks with 5 to 10% pyrrhotite and minor pyrite in the same hole returned values of 0.20 ounce Au per ton and 0.99% Ni over a width of 61 cm (2 feet).

In 1956, subsequent work, located in the southeastern corner of Block 84 was completed by Crowpat Minerals Limited (Table 16). It consisted of a diamond-drill program of 15 short holes, totalling 141.5 m (464.5 feet). The drilling intersected Archean volcanics, Proterozoic Huronian sedimentary rocks and Nipissing diabase. Mineralization reported in the volcanic rocks included disseminated and minor massive pyrite and galena. No assay data is available.

Later work adjacent to the southern margin of the map area was completed by Coniagas Mines Limited (Table 16) in Block 91 of Gillies Limit Township. In 1956, Coniagas completed 4.8 km of magnetic geophysical surveys over a sulphide showing. Two magnetic anomalies striking 070° were delineated parallel to the suspected mineralized zone. According to the report, magnetic intensities from these anomalies were interpreted as massive pyrrhotite mineralization. Subsequently, Coniagas drilled 7 diamond-drill holes totalling 369 m (1211 feet). Mineralization encountered consisted of minor pyrite, minor to massive pyrrhotite and limonite. Twenty-three assay samples were analyzed and indicated values of 0.05 to 1.7% Cu and 0.03 to 0.51% Ni over an average width of 1.5 m (5 feet). Some trenching and stripping of the magnetic anomalies followed but no more assay values are reported.

Between 1952 and 1971 exploration was done by Nickel Rim Mines Limited (Table 16) in the Rib Lake-Whitney Lake area. This area also straddles the southern margin of the map area.

In 1963, 21 diamond-drill holes totalling 3585 m were completed on the claim group. Four of these diamond-drill holes totalling 313 m (1027 feet) are in the map area and intersected fine-grained peridotitic volcanic rocks and minor feldspar porphyry. The only mineralization noted was minor chalcopyrite in white calcite intersected in hole No. 4 at 41 to 48 m (135.1 to 157.5 feet). Serpentine, talc and carbonate occur as typical ultramafic alteration minerals.

In 1971, both VLF-EM and magnetic ground surveys were completed over the property. Several east- and southeast-trending conductors and anomalous magnetic zones outlined by the surveys were subsequently drilled. Minor pyrite, chalcopyrite, pyrrhotite, hematite and magnetite hosted in peridotitic and mafic volcanics and intrusive rocks were intersected in these holes. Three holes totalling 494 m (1619 feet) were drilled at 3 separate locations within the southern margin of the Bay Lake map area. Presumably the geophysical anomalies were explained by the minor amounts of mineralization intersected in each drill hole. Numerous other holes drilled on other parts of the property to the south of the map area will not be discussed in this report.

GEOLOGY

The Whitney Lake-Rib Lake area is underlain by Archean volcanic rocks comprised mainly of mafic volcanics typical of komatiitic basalts and lesser ultramafic synvolcanic intrusive rocks. There probably are some true ultramafic and komatiitic flows in the area but they have not been recognized by the authors in the southern portion of the Bay Lake area. Past reports, however, suggest they exist just to the south around Whitney Lake.

Numerous geophysical conductors and magnetic anomalies have been outlined, some have been drilled and indicate minor amounts of pyrite, chalcopyrite, pyrrhotite and pentlandite. Assay values from the sulphide zones indicate up to 1% Ni and up to 1.3 ounces Au per ton over a potential width of 4 m in a sheared, and altered mafic tuff. Thus, the scattered mineralization and favourable geology makes the Whitney Lake-Rib Lake area a good exploration target for both base metals and gold. Nickel-associated mineralization occurs in an Archean mafic volcanic and/or intrusive geological setting.

RECOMMENDATIONS FOR FUTURE EXPLORATION IN THE BAY LAKE AREA

Throughout the Bay Lake area there are numerous minor sulphide occurrences. Further prospecting could result in the discovery of more significant silver, gold and/or base metal mineralization. The geological environment of the Bay Lake area is analogous to the Cobalt Camp (Legun 1986; Andrews et al. 1986) and thus further prospecting and exploration for Cobalt-type mineralization is recommended in the map area.

The 4 potential areas for finding cobalt-, copper-, $\pm$ silver-, and gold-bearing veins have been outlined in detail in the previous section. These areas are along the upper and lower contacts of the main east-west-trending diabase sills or along several north- and northeast-trending narrow (70 to 140 m wide) dikes in Coleman Township. Areas where Archean metavolcanics and interflow sediments and also sediments of the Coleman Member of the Gowganda Formation are in contact with Nipissing diabase are prime exploration targets.

The presence of mineralized veins is structurally controlled. The veins occur in parallel fracture zones near margins of the diabase. As a general rule, values of cobalt, silver, copper and gold are usually higher in calcite rather than quartz veins. In addition to sporadic cobalt and copper values, there are some gold values of more than 1 ounce Au per ton. These are associated with several cobalt-copper showings (including types 1, 2 and 3) all hosted within Early Proterozoic Nipissing diabase. They include the Portage Bay occurrence and the Shakt-Davis Mine, (both located in the Bay Lake area); the Sugarloaf Island occurrence in Brigstocke Township (Born and Burbidge, in press); and the Temagami-Lorrain occurrence in Cassels Township near Temagami (Born 1989).

Several high gold and minor nickel values were also reported from drill data of sheared and silicified Archean tuffs in the Whitney Lake-Rib Lake area. These values are 1.3 ounces Au per ton over a minimum of 1.83 m and a maximum of 4 m.

Archean metavolcanic and metaplutonic rocks with numerous gold and base metal occurrences underlie the ground moraine terrain located in the southwest part of the map area. In this high potential area both soil and till sampling could outline some significant geochemical anomalies.

In areas of hummocky moraine however, the till is much thicker, the lateral extent is greater, and the distance of transport may be much further from its source. Drilling may also be difficult due to the presence of boulders and sand and gravel lenses. Thus, geochemical prospecting is less likely to succeed in these areas.

Geochemical prospecting in organic terrain can be successful if the depression is hosted in a more favourable bedrock or ground moraine area rather than in a less favourable hummocky moraine terrain.

Elsewhere, high silver values are reported from drill data and indicate values of up to 90 ounces Ag per ton over a width of 5 cm. These holes were drilled east of Shumann Lake in the northeast corner of the Bay Lake area. This is also the area in which a boulder of silver

float containing 11 000 ounces of silver was discovered in 1934. Other high values include 96 ounces per ton of a smaltite ore sample taken from the Shakt-Davis Mine west of Portage Bay.

All these occurrences are good indications of base and precious metal mineralization and make the study area and neighbouring areas promising exploration targets.

The economic potential of the Early Proterozoic sediments of the Lorrain Formation and the underlying Gowganda Formation is low. Potential paleoplacer gold deposits in the Lorrain Formation are unlikely because the depositional environment probably represents marine reworking of fluvial sediments during episodic marine transgressions. Thus, any gold that possibly had been concentrated in the fluvial stage was dispersed during the marine transgression.

Although few sulphide occurrences are found in the Firstbrook Member of the Gowganda Formation there is some potential for sediment-hosted stratiform copper mineralization (Donaldson et al. 1986). Several of the typical elements of such deposits include the red beds represented by the middle and upper parts of the member. Thick turbidite beds could act as an aquifer and the underlying local tholeiitic basalts as a source rock. Finally, the host rocks are the drab-coloured (anoxic) lower Firstbrook Member that commonly contains some disseminated pyrite. The lower unit also probably contains some organic carbon that could act as a reductant to high-Eh fluid-dissolved metals (Donaldson et al. 1986).

In the underlying Coleman Member most of the rocks are debris flows and some of the contained sulphides are primary and detrital in origin. The majority of the sulphides are, however, probably secondary. Thus, the occurrence or absence of most sulphides adjacent to the veins probably represents secondary, structural parameters related to vein emplacement. Such processes would probably include sulphide mobilization during vein formation or emplacement of the Nipissing diabase sills. Thus, the potential for primary base metal deposits in the Coleman Member is less promising than in the overlying Firstbrook Member.

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CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	Multiplied by	Gives	Imperial Unit	Multiplied by	Gives
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 02	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.308 0	cubic yards	1 cubic yard	0.764 555	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 908 8	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

**MAPS
NOT
FILMED**

**CARTES
OMISES**